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ODP # 81-824

ORD-559-81

19 May 1981

MEMORANDUM FOR: Distribution

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FROM: [redacted]
Information Systems Research Division
Processing and Analysis Technology Group
Office of Research and Development

SUBJECT: RECON Security Mechanism Development Project
(Conclusion of Initial Phase)

1. The initial phase of the RECON/COINS security mechanism development has resulted in the preparation of two reports. Security problems involved with connecting the Agency's RECON system to COINS network were defined, discussed, and examined. [redacted] were tasked to examine the RECON/COINS problem. [redacted] is under contract to OS/ISSG while the Anderson Co. is tasked by myself as COTR for this project.

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2. The findings of this effort were that while no security mechanism can be devised for a classified data base/network hook-up (i.e., RECON/COINS) which completely eliminates the probability of spillage or unauthorized data dissemination, the method proposed by [redacted] represents a reasonable approach to reducing this risk. The nature of such risk is defined in the attached reports. The certification for use of this approach for RECON/COINS is under review by OS/ISSG.

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[redacted]

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Attachments:
1. Initial Phase Project Report
2. [redacted] dtd
23 December 1980
3. Frey Technical Memo dtd
27 January 1981
4. Copy of [redacted] Memo
(Government comments)
5. [redacted]

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SUBJECT: RECON Security Mechanism Development Project (Conclusion of Initial Phase)

Distribution:
1 - Clarus W. Rice, D/OCR
1 - Bruce Johnson, D/ODP
STAT 1 - [redacted], C/ISSG
1 - C/IHS

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Initial Phase Project Report

ATTACHMENT 1

Project Report
RECON Security Mechanism Development
(Initial Phase)

I. EXEC SUMMARY

Objective

The purpose of this report is to summarize the activities of this initial phase of the RECON/COINS security mechanism development effort. These activities included problem definition and examination of possible solutions to the security aspects of a proposed RECON/COINS hook-up.

Problem Definition Phase

The primary focus of this effort was problem definition. Connection of any classified data base to a network raises certain security issues. The connection of the Agency's RECON data base to the COINS network and the proposed implementation of the RECON data base as the SAFE central index file are examples of such connections.

During the course of this study, pertinent security issues were defined and discussed. Several approaches to the solution of these security problems were examined and compared. Final reports of the [redacted] are attached. A brief summary of each report is provided in section III of this report.

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Overall Recommendation

Of the approaches considered, the Guard Device concept offers the greatest flexibility, lowest overall cost, least system impact, and the most reliable protection from spillage and unauthorized dissemination.

Although the Guard Device approach offers much and suggests a wide range of possible application, there exists some limitations to the protection it can provide. These few, but significant, limitations are discussed in detail below.

It is my technical opinion, and study results indicate, that the RECON system cannot be connected to any network (i.e., COINS) without some probability of spillage or unauthorized dissemination due to guard malfunction. Additionally, the Guard Device approach will require some change to RECON data base maintenance and update procedures. The requirement for an authenticator attached to each releasable record will increase the total data base size by about 5 percent.

Summary

The security methods examined during this effort were compared on the basis of the requirements for correct operation of the associated computer systems, the feasibility of implementation, the cost (dollars, resources required), and the system operation impact. The guard device concept offers the best solution under these criteria, and also the highest reliability. It could be implemented with off-the-shelf components, and the complexity of the device would be minimal. This is significant because an increase in device complexity is accompanied by increased difficulty in verification of correct device operation.

II. SUGGESTED SOLUTIONS

STAT [redacted].

The approach proposed by [redacted] has a large assumption set. Many elements must work correctly and be trusted for this approach to work properly. Thus, [redacted] was requested to document these assumptions. The result is the attached "Technical Memorandum" dtd 27 January 1981. The [redacted] approach will increase the reliability of the communication process between the front-end (COMTEN) and RECON host processor (IBM 370/168). This approach does not address the releasability problem in the event of RECON system compromise or compromise of the COMTEN front-end processor. This is a prime constraint. STAT STAT STAT

STAT The [redacted] approach offers a method for controlling the synchronization of trusted processes. It does not address the problem of dissemination control, which is the purpose of this project.

STAT [redacted]. (Guard Device)

The Guard Device approach offers the most coverage of all suggested methods. Its assumption set contains only one element (proper operation of the authenticator subsection of the guard device). The structure of this subsection is outlined in the appendix to the attached [redacted] report. The guard device approach moves the security problem from the RECON system to the guard device authenticator subsection. Malfunction or compromise of this subsection can defeat the security effort (only if accompanied by a simultaneous failure or compromise of RECON or the RCC network). The [redacted] uses the figure of ~ $5/10^{20}$ as the probability of guessing the proper cypher-block-chaining (DES) key. The vendor supplied MTBF data for components implementing a guard device would provide a more meaningful measure of the total system reliability. Generally speaking, MTBF figures are higher (greater malfunction probability) than the DES compromise figures of $5/10^{20}$. STAT STAT

III. SUMMARY

[redacted] was asked to comment on the [redacted] approach. These comments are found in the first section of the attached [redacted] report. Also attached is an additional copy of the Frey report with my handwritten comments. The findings of this, the initial phase of the Recon Security Mechanism Development project, have shown *no method* can be devised which does *not* offer some probability of *spillage* and/or unauthorized dissemination due to security mechanism malfunction and/or compromise. Also, the implementation of any security mechanism *must* increase data base size and maintenance requirements.

[redacted]

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[redacted] Technical Memorandum
23 December 1980

ATTACHMENT 2

Technical Memorandum

AN ALTERNATE APPROACH TO SOLVING THE RECON "SECURITY PROBLEM"

23 December 1980

Prepared by:

STAT

[redacted]

Submitted to:

OS/ISSG

Document No. 2102-1123B-10

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[redacted]

INTRODUCTION

This paper addresses the RECON "Security Problem", as described in the document "An Approach to Solving the RECON 'Security Problem'" by [redacted] STAT dated 1 November, 1980. It is assumed that the reader is familiar with the contents of this document, as well as the overall environment characterizing RECON and COINS.

The purpose of this paper is two-fold: first, to provide certain comments concerning the approach proposed in the STAT [redacted] paper, and second, to propose a general approach for the connection of various Customer applications to the COINS network in a secure manner. This paper does not directly address, in any manner, various internal security aspects of RECON which were identified in the [redacted] paper. STAT

[redacted] STAT

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COMMENTS ON THE [redacted] APPROACH

The approach proposed in the [redacted] paper suggests use of a "front-end" processor to determine the releasability of a RECON citation. It appears that such an approach is feasible, and would provide a higher degree of security than that provided by direct connection of COINS to RECON, and we know of no technical impediment or limitation to the general approach. However, an analysis of the proposed approach suggests that several comments are in order:

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1. The front-end processor approach transfers the identified risk of processor manipulation and accidental spillage away from the RECON processor, but provides the same exposure in the front-end processor. While it is expected that the logic involved in the front-end processor will be considerably simpler than that in RECON, and therefore more "trustable", it is contended that the same logical risks apply. The possiblity of accidental spillage due to program error or hardware malfunction remains present in the front-end processor, and it should be noted that most small computers (as would generally be chosen for the front-end processor) possess very limited error detection and correction mechanisms as compared to the processor supporting RECON.

2. The assignment of an authenticator to a citation is addressed from the standpoint of new data entry through specialized input authentication devices, but does not directly address the assignment of authenticators to any existing data bases, nor does it address possible future automatic input of citations from other computerized systems.

3. It appears that the authenticator approach serves to directly prevent the release of "special" information, but does not directly address the possiblity of a user obtaining control of the RECON system through exploitation of a program flaw, etc. It is assumed that if a user could do this, he could not obtain any information since release of the information would be denied by the front-end system. However, in this case compromise could occur if there were any software routine which assigned authenticators available on the RECON system, as might be the case if any "conversion" of existing data bases were attempted.

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[redacted]

4. Following the logic in (3) above, direct compromise of the RECON system itself could possibly allow the user to obtain releasable citations and their corresponding authenticators, which could be conveyed to the user through a covert channel (the citation would appear directly). As the same DES key would apparently be used for all citations, it appears that cryptographic analysis could then be used to determine the DES key in use.

so what?

5. A single DES key appears to be postulated, and this same key would be used "forever." This approach provides only a single level of security (releasable versus non-releasable) and does not directly address the periodic changing of the security key. While this periodic changing of the key is possible through re-routing all of the citations through the authentication device, this would imply that the authentication device was accessible to the RECON computer, and could therefore possibly be compromised through a compromise of the RECON computer system.

ILLEGIB

6. Following the general approach of authentication keys, it would appear desirable to have the system support multiple authentication keys, in order to support additional functions such as multiple security levels or the selective release of information to specifically identified COINS users. However, a system supporting multiple keys will have to be concerned with key management, probably on the RECON system itself, which would be subject to direct compromise under the premises which prevent direct connection of COINS to RECON.

While the above comments should not be construed as indicating that the Anderson approach does not enhance the security of a COINS-RECON connection, it suggests that alternate approaches should be considered in order to attempt to address the above issues. In particular, the authors feel that the approach to this problem should address the following issues:

1. Usability on an in-house basis

2. Multiple-level security support

3. Applicability to other applications than RECON

The remainder of this paper sets forth a general approach to supporting connection of application systems to COINS which provide a considerable degree of enhanced security.

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THE "TRUSTED APPLICATION" APPROACH

One of the options set forth in the [redacted] paper is described as "Modify RECON Option," which involves modification of the RECON application to limit releasability of information based upon applications program conventions, as is used in the SOLIS system. The apparent problems with this approach is that the modified application is still subject to potential manipulation by a COINS user, and that performance in the face of a hardware or software error is uncertain. STAT

It is the contention of this paper that modification to RECON to control releasability of citations is a feasible solution, provided that special considerations are taken to ensure that the underlying system cannot be compromised by the COINS user, and that error conditions will not result in leakage of information. A potential method of obtaining these results is the use of a "trusted applications communications protocol" as described herein.

For purposes of this discussion, it is assumed that execution of the RECON application consists of a "session," with the RECON software "interacting" with the user to solicit his request and provide the desired output. Such a session concept is valid even for batch applications, where the user supplies a "card deck" and the system supplies a printed listing. It is further assumed that applications modifications to RECON can support an adequate security system, provided that the applications execute without error, and that the underlying computer system is not manipulable by the COINS user.

The problems associated with the use of a modified RECON therefore seem to be reduced to:

1. Preventing the COINS user from obtaining control of the underlying system.

2. Protecting RECON in the face of hardware and software errors.

In order to meet these goals, we propose the use of a front-end processor, connected in a manner similar to the connection proposed in the [redacted] paper. However, the functions of this processor is not to perform a security release function, but is rather to manage applications sessions

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[redacted]

with a trusted applications program. It is assumed that a modified RECON application is prepared according to the architecture proposed herein, and that the application, as modified, can be trusted.

In this proposal, reference is made to encrypted transmissions between the front-end processor and the RECON processor. It has been assumed that DES will be used as the encryption method, although this is not significant. Encryption need not be provided by a hardware device; software encryption is sufficient.

A COINS to RECON session would begin with a session initiation request sent from the front-end processor to the RECON applications software. This would be done by an initiation message, containing a predefined password. This message would be encrypted by a standard key known as the RECON session master key (RSM) so that the authenticity of the session initiation request can be verified (the RSM key is "secret" to the COINS world). In addition to the password supplied as part of this message, the front-end processor will supply an initial session key (ISK), which is derived through a random process, as well as an initial sequence verification number (ISV), also derived at random.

During the session initiation, the RECON application can accept or reject the connection, based upon the identity of the user requesting the session. This serves as an additional access check beyond those checks provided automatically by COINS.

The RECON application responds with an accept/reject message, which is encrypted by the ISK, in order to allow the front-end processor to know that it is talking to trusted software, and not an imposter routine. This message also establishes the initial transmission direction for use with the session protocol described below. Initial transmission direction can be either COINS to RECON or RECON to COINS, at the selection of the RECON applications software. Note that all keys described herein are used only between the front-end and RECON, and the COINS user does not deal directly with the keys.

At this point, all remaining communication is assumed to be half-duplex, demand-response communication in which messages are interchanged between the two computers on a one-for-one basis. This interchange will utilize the special conventions described below.

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Prior to each message transmission, there will exist both a current session key (SK) and sequence verifier (SV). Prior to the first message transmission, the ISK is the SK, and the ISV is the SV. Each of these numbers is used to ensure that all communication takes place with the trusted RECON application, and that intervening hardware or software errors do not allow security breaches.

Each message transmitted (in both directions) contains a sequence verification number, SV. The proper value of an SV is derived from its previous value through a mathematical transformation known to both processors. Prior to sending a message, each processor will append its calculated "next" SV to the message, with a similar calculation being used by the other processor to check for the proper value. An improper SV in any message will immediately terminate the RECON session, and will be recorded in an audit trail for later analysis.

The purpose of the SV is to provide one level of check that the COINS user and the applications program (RECON) are synchronized with one another. If a hardware or software failure occurs in the RECON processor which requires a restart of the system, no further communication can take place using the same session identifier, as the SV information will be lost and all messages will be rejected.

Each message, which contains both message text and the SV, is encrypted prior to transmission using the current SK. As a result, the message can only be processed by an authorized receiver in posession of the current SK.

In order to guard further against errors resulting in the inadvertent spillage of data, the SK is changed for each message transmission, by defining a new SK which is calculated by applying a block-type cypher (as described in the [redacted] paper) to the preceeding message. This new SK would then be used for the subsequent transmission.

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Because both the SV and the SK change (in a pseudo-random fashion due to the nature of DES) with each message, in an independent fashion, there is no way for either processor to "predict" subsequent keys. As a result, complete secure message synchronization can be maintained between the front-end processor and the trusted application (RECON). At any point at which a hardware or software error disrupts this process, synchronization will be lost and no further communication will be possible.

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[redacted]

The security afforded by this approach depends upon the fact that the front-end processor will only be able to communicate with a trusted application in the host processor, as all communications from the front-end processor will be encrypted. If through some error the front-end processor were to be communicating directly with the host operating system, no meaningful communication could occur, as all the host operating system would see was a meaningless encrypted message.

In this manner, it is possible to ensure that the front-end processor can communicate only with trusted applications programs which are prepared to accomodate the special session protocol defined herein. Communications with non-trusted applications is impossible due to the encryption which is performed. Security of the overall approach is maintained by keeping all key management functions transparent to the COINS user, so that there is no way that a user could "spoof" the system.

The use of varying keys and SV numbers is to guard against interruption of one session with a resulting inadvertent "connection" of the COINS user to other software (or other sessions). Any such error will be detected by invalid SVs or inability to communicate due to a missing or invalid SK.

Of course, the RECON application must still be trusted to enforce its appropriate security policy, and significant errors in the RECON application could result in compromise of information. However, since the RECON application would be responsible for verification of all communication, it would appear to be reasonable to trust its security mechanisms if other "attacks" on the system were closed. This proposed mechanism provides a method of closing all other attack routes through COINS, although other attack routes through RCC would not be closed by this approach.

It should be noted that any errors which occur in the RECON application will not be transmitted to the COINS user, since it is assumed that any error messages (i.e. messages generated by the host operating system) could not be transmitted to COINS, as they would not be properly encrypted for transmission to the front-end. As a result, if any such error occurred, the front-end would receive an apparently meaningless transmission, and would withhold this message from COINS, automatically terminating the session. This check eliminates a considerable number of programming error conditions from the list of possible compromises.

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In this discussion, it has been assumed that the software in the front-end processor can be "secure," along the lines set forth in the [redacted] paper. This application may be a target use of systems such as KSOS or SCOMP. While we have not performed a security analysis of the effects of penetrating the front-end processor, this is not felt to be a significant risk, since encrypted communications would still be required to talk to RECON. The only potential compromise appears to be limited to the case where the front-end processor is compromised and the RECON system is simultaneously compromised, a probably unlikely event.

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[redacted]

SUMMARY

The method proposed above allows the development of a COINS to RECON connection which provides a significant level of security. The front-end computer will only be able to "talk" to the trusted RECON application, as any other program on the host computer will see a meaningless stream of encyphered information. The key change and sequence verification architecture insures that all accepted communications are part of a single session, and that "restarts" or "error recoveries" cannot participate in the session due to a lack of sequence or key information. All encryption and key management is transparent to COINS, and is never a part of the COINS network, but is confined to the host computer and the local front-end. Direct communications between the COINS user and the host operating system is prevented due to the encrypted nature of all transmissions.

While this overall architecture has been proposed to solve the COINS to RECON connection problem, it should be noted that it is equally applicable to communications with any other "trusted applications" which have been coded to obey this proposed session protocol. Individual applications would have unique session master keys (RSM equivalents), and the specification of these keys would control the subsequent SV generation procedure, in order to guard against "crossed wires" in a multi-application environment. In this manner, it would be possible to make other RCC applications available to COINS, as desired, without causing increased security risks.

[redacted] STAT

27 January 1981

ATTACHMENT 3

INTRODUCTION

On 23 December 1980, [redacted] submitted a document entitled, "An Alternate Approach to Solving the RECON 'Security Problem,'" (Document No. 2102-1123B-10) which proposed use of a "trusted applications" communications protocol as a possible method of allowing direct connection of the RECON system to the COINS network. This document made a number of assumptions concerning both RECON and COINS which were critical to the viability of the suggested approach. These assumptions were not documented, and the purpose of this paper is to document these assumptions, as well as to provide certain observations about the implications of these assumptions.

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[redacted]

ASSUMPTIONS CONCERNING COINS AND RECON

The success of the "trusted applications" approach assumes that all of the following assumptions are reasonable:

1. A releasability indicator can be assigned to each RECON citation.

   This assumption merely states that there is some reliable method of assigning a releasability indicator to all citations contained in the RECON/COINS data base. If human judgment is involved in this operation, it is subject to both risks and errors. If, alternatively, RECON/COINS users may see the collateral files but not the codeword files, then this assumption may be valid. As the conditions specifying the releasability of RECON citations are unknown to the authors, we merely present this assumption and cannot comment on any risk involved.

2. It is possible to "dedicate" communications lines between the proposed RECON front-end processor and the RECON applications system.

   The proposed approach assumed that there was a dedicated set of communications channels between the front-end processor and the processor supporting RECON. While this approach was not mandatory, as we saw it, from a security standpoint, it vastly simplified some of the security issues. If, in fact, communications would be over secured facilities, such as the existing COMTENS, then it would appear to be necessary to have the front-end processor enter the existing characters ("REC") required to establish a communication to RECON. As this would be done in plain-text, a compromise of the front-end processor could possibly allow connection to systems other than RECON, thereby presenting a significant potential security risk.

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[redacted]

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[redacted]

3. The modified RECON applications system can be "trusted" as regards security.

> Implicit in the trusted application approach is the assumption that an applications system can be approved from a security standpoint. Obviously, given the state of the art as it sits today, such an approval cannot be placed on a formal methodology, absent the use of some properly-secured technology.

4. The COINS system can be "trusted" to only allow connection of an appropriately cleared COINS user.

> A further implicit assumption of the trusted applications approach was that the security features of COINS could be trusted to allow only properly-authorized users to obtain access to the RECON front-end processor. COINS contains logic structures designed to limit access to properly-authorized individuals. As it is not sufficient to rely upon the security features supplied by COINS, then it would appear necessary to have the front-end processor explicitly validate the access rights of each COINS user. Such a requirement would introduce a potential exposure through compliance of the front-end processor.

SUMMARY

The trusted applications approach implicitly requires each of the assumptions set forth above, or modifications to counter exposures introduced if the above assumptions are invalid.

It must be noted that if either assumption 2 or assumption 4 is incorrect, a significant security compromise could occur in the event that a COINS user were able to compromise the front-end processor. As a result, it would be necessary to "certify" such software system. Given the current state of technology in both trusted computer systems and their formal proof, it would appear to be rather difficult to perform such certification on a formal basis.

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COMMENTS ON THE [redacted] APPROACH

The approach proposed in the Anderson paper suggests use of a "front-end" processor to determine the releasability of a RECON citation. It appears that such an approach is feasible, and would provide a higher degree of security than that provided by direct connection of COINS to RECON, and we know of no technical impediment or limitation to the general approach. However, an analysis of the proposed approach suggests that several comments are in order:

1. The front-end processor approach transfers the identified risk of processor manipulation and accidental spillage away from the RECON processor, but provides the same exposure in the front-end processor. While it is expected that the logic involved in the front-end processor will be considerably simpler than that in RECON, and therefore more "trustable", it is contended that the same logical risks apply. The possiblity of accidental spillage due to program error or hardware malfunction remains present in the front-end processor, and it should be noted that most small computers (as would generally be chosen for the front-end processor) possess very limited error detection and correction mechanisms as compared to the processor supporting RECON.

true

good point

2. The assignment of an authenticator to a citation is addressed from the standpoint of new data entry through specialized input authentication devices, but does not directly address the assignment of authenticators to any existing data bases, nor does it address possible future automatic input of citations from other computerized systems.

no

3. It appears that the authenticator approach serves to directly prevent the release of "special" information, but does not directly address the possiblity of a user obtaining control of the RECON system through exploitation of a program flaw, etc. It is assumed that if a user could do this, he could not obtain any information since release of the information would be denied by the front-end system. However, in this case compromise could occur if there were any software routine which assigned authenticators available on the RECON system, as might be the case if any "conversion" of existing data bases were attempted.

no

updates done off line.

(separate processor)

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[redacted]

4. Following the logic in (3) above, direct compromise of the RECON system itself could possibly allow the user to obtain releasable citations and their corresponding authenticators, which could be conveyed to the user through a covert channel (the citation would appear directly). As the same DES key would apparently be used for all citations, it appears that cryptographic analysis could then be used to determine the DES key in use.

or what?

5. A single DES key appears to be postulated, and this same key would be used "forever." This approach provides only a single level of security (releasable versus non-releasable) and does not directly address the periodic changing of the security key. While this periodic changing of the key is possible through re-routing all of the citations through the authentication device, this would imply that the authentication device was accessible to the RECON computer, and could therefore possibly be compromised through a compromise of the RECON computer system.

no. not necessary to change key

6. Following the general approach of authentication keys, it would appear desirable to have the system support multiple authentication keys, in order to support additional functions such as multiple security levels or the selective release of information to specifically identified COINS users. However, a system supporting multiple keys will have to be concerned with key management, probably on the RECON system itself, which would be subject to direct compromise under the premises which prevent direct connection of COINS to RECON.

While the above comments should not be construed as indicating that the Anderson approach does not enhance the security of a COINS-RECON connection, it suggests that alternate approaches should be considered in order to attempt to address the above issues. In particular, the authors feel that the approach to this problem should address the following issues:

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In order to meet these goals, we propose the use of a front-end processor, connected in a manner similar to the connection proposed in the Anderson paper. However, the functions of this processor is not to perform a security release function, but is rather to manage applications sessions

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[redacted]

with a trusted applications program. It is assumed that a modified RECON application is prepared according to the architecture proposed herein, and that the application, as modified, can be trusted.

no two many invalid assumption

In this proposal, reference is made to encrypted transmissions between the front-end processor and the RECON processor. It has been assumed that DES will be used as the encryption method, although this is not significant. Encryption need not be provided by a hardware device; software encryption is sufficient.

ILLEGIB

[redacted]

A COINS to RECON session would begin with a session initiation request sent from the front-end processor to the RECON applications software. This would be done by an initiation message, containing a predefined password. This message would be encrypted by a standard key known as the RECON session master key (RSM) so that the authenticity of the session initiation request can be verified (the RSM key is "secret" to the COINS world). In addition to the password supplied as part of this message, the front-end processor will supply an initial session key (ISK), which is derived through a random process, as well as an initial sequence verification number (ISV), also derived at random.

During the session initiation, the RECON application can accept or reject the connection, based upon the identity of the user requesting the session. This serves as an additional access check beyond those checks provided automatically by COINS.

The RECON application responds with an accept/reject message, which is encrypted by the ISK, in order to allow the front-end processor to know that it is talking to trusted software, and not an imposter routine. This message also establishes the initial transmission direction for use with the session protocol described below. Initial transmission direction can be either COINS to RECON or RECON to COINS, at the selection of the RECON applications software. Note that all keys described herein are used only between the front-end and RECON, and the COINS user does not deal directly with the keys.

ILLEGIB

[redacted]

At this point, all remaining communication is assumed to be half-duplex, demand-response communication in which messages are interchanged between the two computers on a one-for-one basis. This interchange will utilize the special conventions described below.

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[redacted]

Prior to each message transmission, there will exist both a current session key (SK) and sequence verifier (SV). Prior to the first message transmission, the ISK is the SK, and the ISV is the SV. Each of these numbers is used to ensure that all communication takes place with the trusted RECON application, and that intervening hardware or software errors do not allow security breaches.

Each message transmitted (in both directions) contains a sequence verification number (SV). The proper value of an SV is derived from its previous value through a mathematical transformation known to both processors. Prior to sending a message, each processor will append its calculated "next" SV to the message, with a similar calculation being used by the other processor to check for the proper value. An improper SV in any message will immediately terminate the RECON session, and will be recorded in an audit trail for later analysis.

The purpose of the SV is to provide one level of check that the COINS user and the applications program (RECON) are synchronized with one another. If a hardware or software failure occurs in the RECON processor which requires a restart of the system, no further communication can take place using the same session identifier, as the SV information will be lost and all messages will be rejected.

Each message, which contains both message text and the SV, is encrypted prior to transmission using the current SK. As a result, the message can only be processed by an authorized receiver in posession of the current SK.

In order to guard further against errors resulting in the inadvertent spillage of data, the SK is changed for each message transmission, by defining a new SK which is calculated by applying a block-type cypher (as described in the Anderson paper) to the preceeding message. This new SK would then be used for the subsequent transmission.

Because both the SV and the SK change (in a pseudo-random fashion due to the nature of DES) with each message, in an independent fashion, there is no way for either processor to "predict" subsequent keys. As a result, complete secure message synchronization can be maintained between the front-end processor and the trusted application (RECON). At any point at which a hardware or software error disrupts this process, synchronization will be lost and no further communication will be possible.

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In this discussion, it has been assumed that the software in the front-end processor can be "secure," along the lines set forth in the [redacted] paper. This application may be a target use of systems such as KSOS or SCOMP. While we have not performed a security analysis of the effects of penetrating the front-end processor, this is not felt to be a significant risk, since encrypted communications would still be required to talk to RECON. The only potential compromise appears to be limited to the case where the front-end processor is compromised <u>and</u> the RECON system is <u>simultaneously</u> compromised, a probably unlikely event.

no. bad assumption

STAT

[redacted]

SUMMARY

The method proposed above allows the development of a COINS to RECON connection which provides a significant level of security. The front-end computer will only be able to "talk" to the trusted RECON application, as any other program on the host computer will see a meaningless stream of encyphered information. The key change and sequence verification architecture insures that all accepted communications are part of a single session, and that "restarts" or "error recoveries" cannot participate in the session due to a lack of sequence or key information. All encryption and key management is transparent to COINS, and is never a part of the COINS network, but is confined to the host computer and the local front-end. Direct communications between the COINS user and the host operating system is prevented due to the encrypted nature of all transmissions.

While this overall architecture has been proposed to solve the COINS to RECON connection problem, it should be noted that it is equally applicable to communications with any other "trusted applications" which have been coded to obey this proposed session protocol. Individual applications would have unique session master keys (RSM equivalents), and the specification of these keys would control the subsequent SV generation procedure, in order to guard against "crossed wires" in a multi-application environment. In this manner, it would be possible to make other RCC applications available to COINS, as desired, without causing increased security risks.

significant amts of
assumption and constraints.

STAT

Next 1 Page(s) In Document Exempt

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Page

Illustrations

ACKNOWLEDGEMENT

The idea of using a cryptographic checksum to authenticate a decision regarding releasability was originally conceived by Lt. Col. Roger R. Schell, USAF, in connection with another application. Lt. Col. Schell was consulted on the conceptual development of the approach. The contribution of Mr. [redacted] ORD/ISRD, to the implementation method of permitting data records to "belong" to two or more use groups and in providing the functional hardware design examples in the appendices is cheerfully acknowledged.

1. INTRODUCTION

This report describes the results of a feasibility study of an approach to solving the security problems associated with attaching the RECON bibliographic system to an external network. The problems were surfaced in considering the attachment of RECON to the COINS network in order to extend the services of RECON to the Intelligence Community as a whole. While the study has concentrated on the technical aspects of the problem, it has addressed some of the procedural aspects as well.

In the balance of this report, we will briefly review the RECON application, identify the security problem, discuss the COINS network, review other approaches considered, and then describe the recommended approach.

2. THE RECON SYSTEM

RECON is an on-line interactive bibliographic reference system maintained and operated by the sponsor at his headquarters. Its host computer is a 370/168 system which is one element of the [redacted] Computer Center complex (RCC). The RECON data base is a subject file index of intelligence reports from all over the Community. The data base contains citations for both raw and finished intelligence reports including collateral and SCI. STAT

The RECON system is complemented by an in-house Automated Document Storage and Retrieval System, ADSTAR, which stores source documents in digitized form on microfilm. RECON currently serves approximately 130 terminals in the sponsor's organization through two COMTEN front-ends.

The data base contains two kinds of records: collateral and SCI. A RECON user may specify which file(s) he wishes to search (collateral, SCI, or All (meaning both)).

The RECON user interacts with the application through 20 commands, one of which is an implied SEARCH. The RECON implied SEARCH command produces a set of records that meet the search criteria. The result sets are associated with a user's work space and can be combined or limited in various ways after a search has taken place. It is possible to combine the results in two or more sets through logical operations (e.g., one can create a set STAT (1) on [redacted] and another set (2) on [redacted] then logically combine the STAT sets 1 AND 2 instead of having to specify that intention in the initial STAT search as [redacted]

RECON has the ability to manipulate sets to create combined sets which may then be edited to print records or any selected fields of a RECON record.

The RECON application is interactive, although an overnight batch and a canned query capability exists.

3. THE RECON SECURITY PROBLEM

3.1 The RECON Security Environment

In the RECON files, there are broadly speaking two kinds of titles, those which can be widely distributed and those whose distribution is restricted because they are compartmented, proprietary, or originator-controlled.

The type of distribution accorded to the "restricted" group is complex because of a desire to avoid the absurdities that can arise from an originator being denied access to a title that he created and contributed to the system under an originator-controlled label because the system applies a rule preventing distribution of originator-controlled titles. Thus, the problem cannot be solved merely by denying all external access to the restricted group of titles.

Presently in RECON, access is controlled to:

a. The RECON application (via logon-id and password).

b. The collateral or codeword (sub)files (via authority presumably contained in the user's identification record).

c. Modify and/or update commands (via authority contained in a separate SECURITY data set).

No other access control is provided.

3.2 Operative Aspects of the Security Problem

Due to limited resources, the sponsor makes no attempt to validate manufacturer-supplied changes to the operating systems (MVS, VM, JES3) or vendor-supplied software packages. As a consequence, it must be prudently assumed that trapdoors exist in some or much of the sponsor's software or operating systems. The degree of threat this poses is a function of how much trust one has in the user population and the accessibility of the systems.

The sponsor has what appears to be unlimited trust in its own personnel due in part to the high standards established for clearance and a program for updating personnel investigations at nominal five-year intervals.

In connection with making RECON available to Community personnel, the sponsor correctly asserts that not all Community organizations apply the same clearance standards for access to SCI. In particular, the Military Departments apply substantially different investigative standards for clearances and SCI access. The Military Departments do not require an extended background investigation of its personnel for Top Secret clearance, and they do not use polygraph examination to verify background and investigative information about an individual.

Because of this, the sponsor asserts that the reliability of that segment of the Community is unknown and that the sponsor cannot fulfill its obligations to protect highly classified and sensitive information by giving unrestricted access to one of its systems to Community personnel.

With regard to the accessibility issue, it is obvious that putting RECON on a Community network increases its accessibility. What is less obvious is that RECON is on an internal network of substantial dimensions. If RECON is compromised to permit manipulation of the system upon which it resides, the compromise could be used to compromise the entire sponsor's internal network.

Thus, the sponsor's concerns are twofold. First, if RECON becomes accessible to user population of essentially unknown reliability, it could be potentially subject to external penetration by activating a trapdoor in the RECON application, or the underlying operating system that could be used to recover information, manipulate information, or deny service to RECON or other parts of the sponsor's internal network. Second, there is a corresponding concern that hardware or software failure in the sponsor's internal network would increase the risk of accidental exposure of sensitive information due to spillage on the external network.

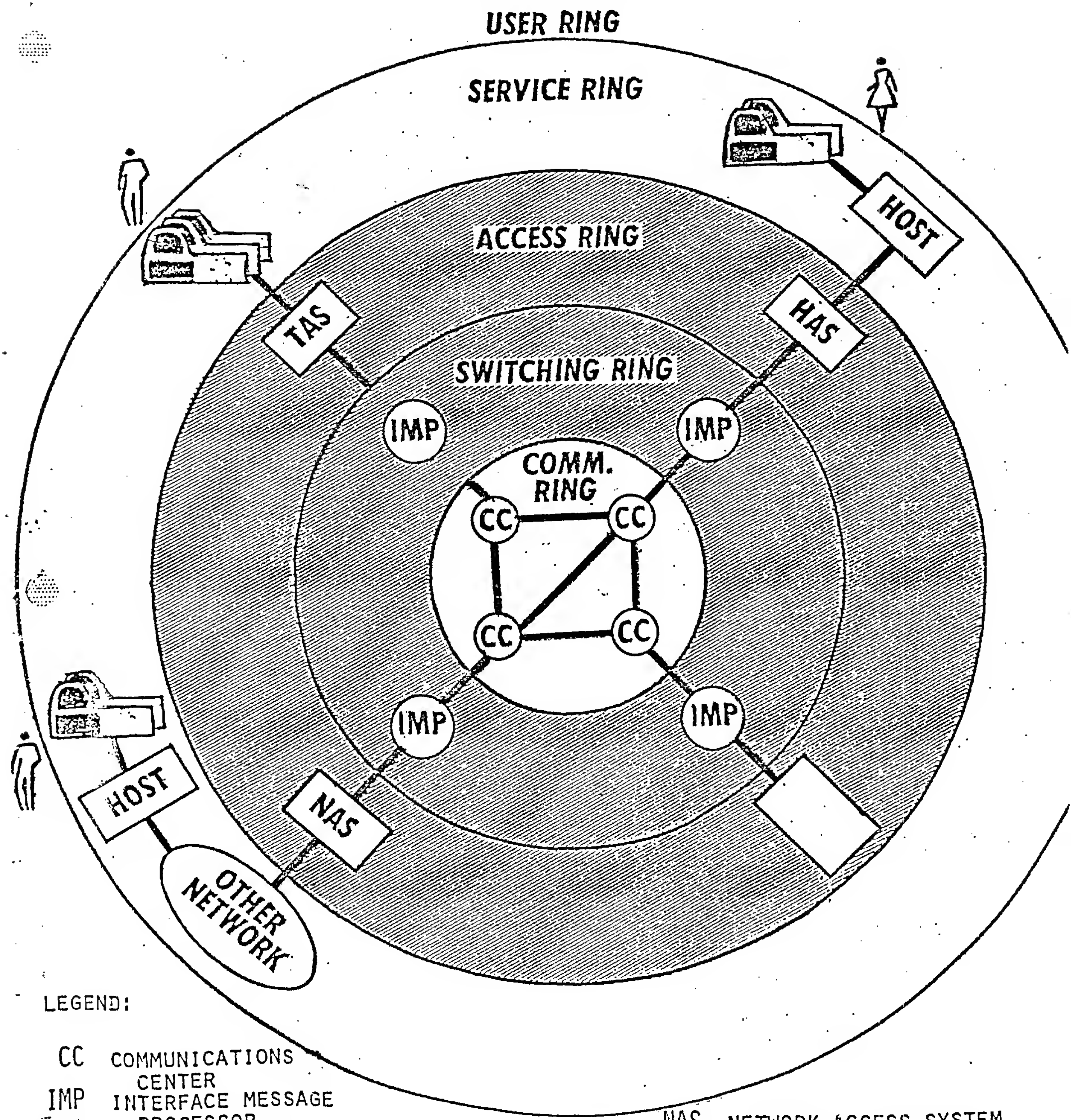
4. COINS

The COINS network has the structure shown in Figure 1. The packet switched nodes are ARPANET IMPS, interconnected by full period link-encrypted channels of the Tetrahedron communications network. At the next level, a series of interface processors is found that interfaces terminal users, server-hosts, and other networks to COINS. The interface processors, known collectively as CAS's (for COINS Access Systems), are PDP-11's running UNIX and special network software. All CAS's have network protocol software (currently NCP), software to perform logging of CAS activity for network management purposes, and access control software.

Depending on the principal function of the CAS (terminal/user support, server-host interface, network interface), function-specific software is also found. In the case of Host Access Systems (HAS), the HAS's host interface is further specialized to interface to the specific hardware of the server-host. (It will emulate the environment expected by the server-host (e.g., a channel of a specific transfer rate, etc., and the minimal protocols needed to coordinate transfer of information between systems.)

COINS users interface to COINS from terminals, either through a user's local host or through a Terminal Access System (TAS). COINS users have a restricted functionality both with respect to the data bases they query and with respect to the TAS's and hosts through which they access the network. With respect to the data bases, COINS users cannot do more than request data. A COINS-based analyst can frame queries either in the native language of the query system or, if he or she accesses COINS through a TAS, the queries will be able to be stated in a network virtual query language known as ADAPT. The ADAPT query is translated into the native language of the target system

COINS II
RING ARCHITECTURE CONCEPT



LEGEND:

CC COMMUNICATIONS CENTER
IMP INTERFACE MESSAGE PROCESSOR
TAS TERMINAL ACCESS SYSTEM
HAS HOST ACCESS SYSTEM
NAS NETWORK ACCESS SYSTEM
▨ COINS PMO ZONE OF CONTROL
TERMINALS

Figure 1

for the user. Once at the target system application, a COINS user's query is treated just the same as any other query; it is interpreted by the application's software to produce the requested data. The COINS user cannot affect the software or the data base. He is unable to change anything in the server-host system since the server-host is interpreting the request.

All analysts and their terminals in COINS are cleared Top Secret SI/TK as are all computer sites. The network operates in a Top Secret SI/TK System High mode (as defined in DCID 1/16).

The access systems provide the capability of enforcing NTK in two forms. First, an agency may wish to restrict access by some of its personnel to some of the data on the COINS (or other attached) network. It can do so by omitting the access privilege when the user is made known to the CAS. Second, access systems can control access to applications or hosts that they support through use of a host-agency supplied access list identifying by name those users who may execute the application or access the host. The HAS can also (if directed by the server-host/agency) grant access by Agency or other smaller organizational groups.

Additional detail about COINS security can be found in Appendix A.

5. SUMMARY OF PREVIOUSLY CONSIDERED APPROACHES TO THE PROBLEM

A number of approaches have been previously advanced for solving or avoiding the RECON security problem. This section will review them.

5.1 Separate Systems

In an earlier examination of the problem, it was proposed by the sponsor that a separate computer system be provided to store and make accessible to the Community those bibliographic entries not deemed "special" as discussed above. Several subsets of this approach were considered; however, the approach was rejected because of the cost of maintaining duplicate facilities. The approach protected the sponsor's assets from penetration and exposed that portion of the data base, even if the system were penetrated, only to individuals who would be authorized to access the information under any circumstances.

5.2 Multi-Level Secure Operating Systems

As a way of defeating internal penetration by programming users, the notion of applying multi-level secure operating system technology (e.g., KSOS) to the host supporting RECON was considered.

This approach, in principle, would go far to defeat direct attacks and, if the software change controls proposed to assure the continued security properties of such systems were in place, it would defeat the placement of trapdoors and Trojan Horses. Note, however, that if a trapdoor were placed in KSOS, it would be vulnerable to external attack in the same way as the existing RECON system.

However, the realities of the technology are such that KSOS cannot currently be applied to large existing systems such as 370/158's without changing the operating system and programming interface to produce totally incompatible (with anything!) systems. Coupled with costs estimated in the millions, the approach is not feasible in this environment.

5.3 Filters

The addition of filters to the RECON system software has been examined as a means of using the inherent capabilities of RECON to limit access to just those records deemed releasable based on security, dissemination, and codeword codes located in the RECON records.

If the classification, codeword, and dissemination codes are used in combination to identify material that is not to be released to external (i.e., network) users, the preferred approach is to (invisibly to the user) apply a filter consisting of a series of AND NOT < dissemination codes and codeword codes > to each (implied) SEARCH command issued by a user to exclude restricted material from the search. (A similar scheme involving canned queries is currently used by OCR personnel who now perform RECON searches for the Community.)

The filter approach provides the granularity of access control needed to restrict access to the subset of the RECON data base considered releasable; it does nothing to control the threats of internal or external penetration. Nevertheless, the application of filters to queries originating from network users will greatly simplify the design and operation of the GUARD system discussed below. An approach to implementing filters for RECON is outlined in Appendix B.

6. AUTHENTICATED RELEASABILITY

6.1 Technical Approach

At one level, the RECON security problem is akin to the problem of "sanitizing" SCI in order to release it to activities without the proper clearances. The general approach in sanitizing systems is to permit arbitrary queries by all users, but to route the results of the queries of uncleared users to a sanitization officer who would manually examine the output before releasing it.

In low-volume situations, all sanitization officer activity could be manual. In higher-volume situations, the use of a computer-based GUARD station to support the sanitization officer (W0079) has been developed.

While the sanitization officer/GUARD station approach would work in principle, it is not a practical solution for RECON because of the excessive delays that would be imposed by the sanitizing officer. These delays would cascade to produce response times that border on the infinite.

What is proposed to solve the RECON problem is to adopt the idea of a GUARD station, but to automate the identification of releasable citations to minimize the bottlenecks cited above.

6.2 Concept of Operation

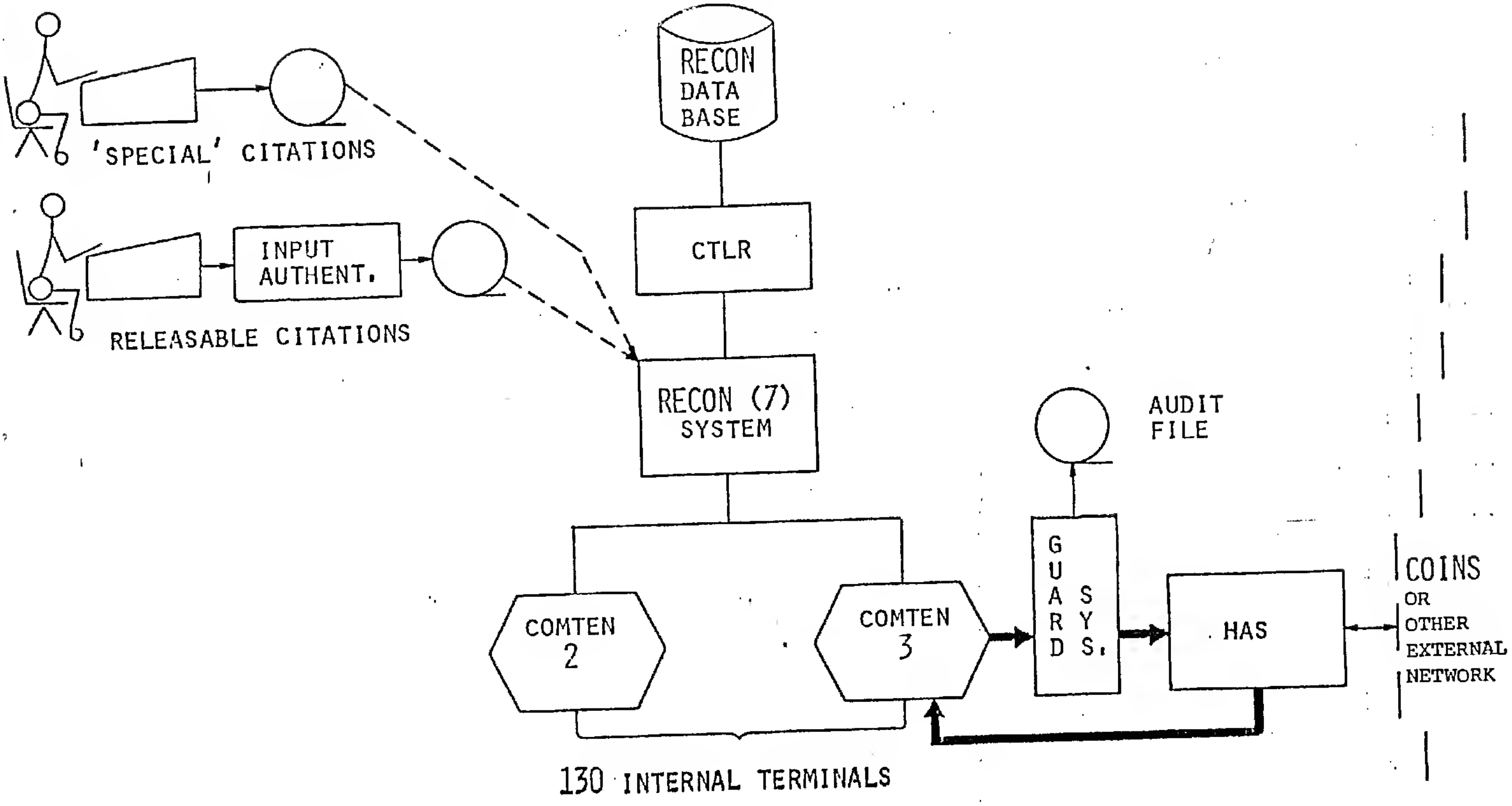
For the purpose of exposition, we will first consider <u>all</u> citations in RECON categorized either as releasable (to external network users who do not possess access approvals for the "special" citations) or NOT releasable to those individuals. For each RECON entry designated by the originator as releasable to external users, a cryptographic checksum, which is a function of the entire record, is computed by a special authentication device as the data is entered into the system. The checksum is appended to the record and stays with the record forever.

Upon being selected for output, <u>all</u> records for a specific destination are routed to a dedicated system (the GUARD processor) where the cryptographic checksum is recomputed. If the recomputed value is <u>identical</u> to the checksum appended to the record when it entered the data base, the entry can be released without further review. If the checksum check fails, the item will not be forwarded to the requestor and the record, destination, etc., will be written to an audit file.

Each RECON entry designated as "releasable" (i.e., NOT "special") will be processed through one of a set of input terminals that cause the entry to be routed through the input checksum generation device (see Figure 2) as part of preparing it for entry into the data base. The input checksum generator computes a unique, non-forgeable checksum which is appended to the entry before it is entered into the RECON system. If the entry and its checksum are subsequently forwarded to the GUARD interface for release, the checksum value is recomputed at the GUARD.

6.3 <u>Properties of the Cryptographic Checksum</u>

The principal problem that this approach raises is assuring that the checksum cannot be forged. This is solved by using a modern cryptographic techn6que, the National Bureau of Standards Data Encryption Standard (DES), and performing the checksum function outside of the RECON host on dedicated systems, one for computing checksums on input entries, the other for the



TECHNICAL APPROACH
TO RECON SECURITY PROBLEM

Figure 2

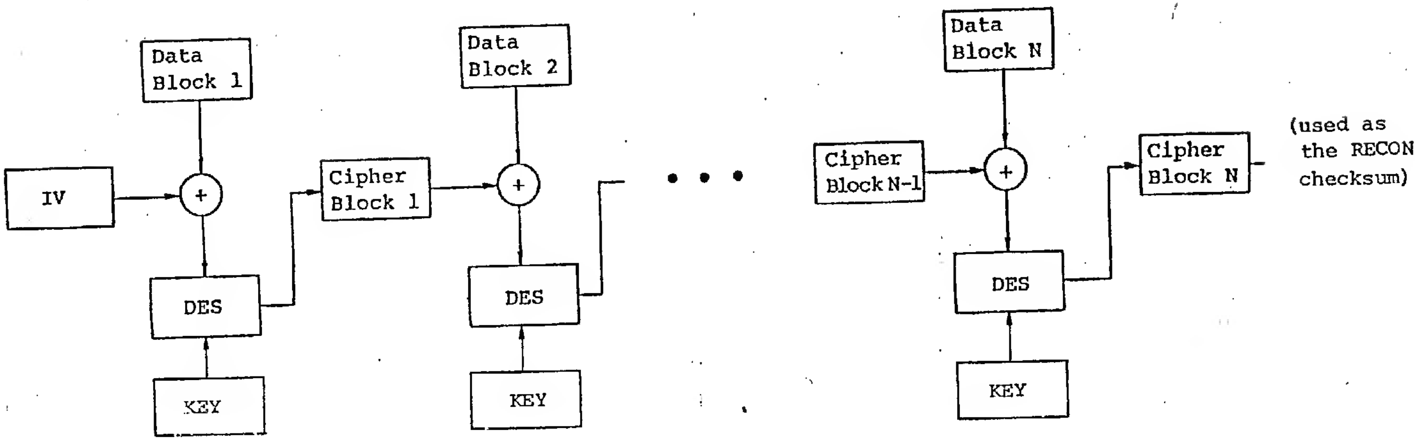
GUARD function.

The crypto checksum of the original entry is produced using a secret key known only to the input checksum device and to the GUARD interface processor(s). The key is NEVER available within the RECON system per se.

The crypto checksum is produced by block-chained encipherment of the releasable entry (see Figure 3). In block-chained encipherment, the ciphertext of each block of the item being enciphered is dependent on the contents of all previous blocks. The last block of an item is dependent on the entire entry and is used as the checksum. The secret key for this mode of use is 120 bits long (64 bits for the IV (the Initial Variable, used to provide the first value exclusive OR'd to the first block of plain text), 56 bits for the DES key).

The DES has a particularly attractive property for use within an application. As little as a one-bit change of the data being encrypted (or decrypted) will result in approximately 50% of the ciphertext (plaintext) bits being changed. This provides an excellent error (or tampering) detection quality to the scheme.

With the cryptographic checksum keys physically isolated from RECON and other RCC computers, the only other method of forging a checksum is to pick a 64-bit number at random and attach it to a RECON record. The probability of picking a "correct" checksum by accident is $\frac{1}{2^{64}}$ (the size of the checksum) or $5.24\text{x}10^{-20}$.



(used as the RECON checksum)

- ⊕ Exclusive OR
- The secret key(s) are the Initial Variable (IV) and the KEY.

BLOCK CHAINING

Figure 3

In summary, the protection against forgery is provided by protecting the key. Key protection is provided by:

a. Physically separating the input and GUARD authentication machines from the retrieval processor.

b. Hard-wiring the key on the DES-board so that it is not even readable by the GUARD or input checksum generator.

c. Providing a security "kernel" in the GUARD and input checksum generator to control their operation. Because of the single-function nature of these devices, this kernel is simple in structure and offers no technical risk.

6.4 Security Properties of the Approach

Assuming that the GUARD system works as described and it is interposed between RECON (and its internal network) and an external network as shown in Figure 2, this approach has several interesting properties with respect to the RECON security problem. First, no failure or compromise of hardware or programs in the RECON host or its network will permit data to spill from the Agency internal network to the Community network. Second, no manipulation of RECON or its host processor (or the internal network) will release special or other material across the GUARD interface.

This is because the GUARD system will be designed to only deal with what it thinks are RECON records, and to escape the GUARD, a cryptographic checksum is recomputed from the just to be released record. If this checksum does not identically match the checksum computed when the record entered the RECON application, the record does not get released.

If a checksum gets detached from its citation at any time subsequent to its creation, the only loss will be that the entry which was considered releasable will NOT be available to Community analysts. The scheme is fail-safe. It should also be obvious that the approach will not spill special data if a checksum gets attached to a "special" citation, or either the citation or checksum is manipulated by accident or design since the change of as little as one bit of either component will result in a different checksum being recomputed on output.

The approach does not directly address the threat of manipulating a system through activating trapdoors from external users to manipulate data or deny service. Manipulating data through an essentially one-way trapdoor (since the GUARD permits NO unauthorized data transmission out of RECON) is a question of how much detailed information it is assumed the manipulator has (or is able to get) from internal sources to guide his attempt at manipulation. Nevertheless, such manipulation will not cause the release of unauthorized data.

The threat of denial of service through activating trapdoors is more realistic since not too much has to be known about the target in order to foul it up. Since the threat cannot be countered by the GUARD approach, the only solution evident at this time is to shut down the external network connection when and if denial of service attempts are detected.

The single remaining security question is what happens if the GUARD system fails? While of itself no guarantee, the simple function of the GUARD will reduce the opportunity for design and implementation errors. In addition, advanced design techniques, such as formal specification, can be applied to the GUARD design to further increase the confidence in the reliability of the system. Since it is envisioned that the GUARD will be implemented in an advanced microprocessor (see Appendix C), once the program has been thoroughly checked out, it can be placed in a Read-Only Memory (ROM).

If the hardware of the GUARD fails, it must fail in such a way as to bypass the recomputation of the cryptographic checksum. Even then, the only real risk is if the GUARD fails and RECON fails or is subverted at the same time. The interface between the GUARD and RECON is simple enough that there does not appear, at this point, any way in which the RECON system can induce a failure of the GUARD.

Finally, the GUARD can be designed in such a way as to permit RECON to test the correct operation of the GUARD by addressing various kinds of records to itself. The only records that should return are those whose checksum is correctly recomputed. (If there is a concern that a subverted RECON could use this facility to generate and test "random" checksums, it might be noted that it would take about 58,494 years to systematically try all possible 2^{64} checksums against a single record. At the rate of 10,000,000 trials/second (100 ns/trial) on average, one could expect to find the correct checksum in one-half the time, or 29,247 years.)

6.5 Security-Derived Modifications to RECON

It would be nice if the GUARD approach could be applied as is, with no effect on RECON, and while providing the same interface to all users. Unfortunately, due to the concern for covert (and direct) channels that would permit transmission of unauthorized data outward to an external network, this is not the case.

Because of these concerns, it appears that the following changes will be necessary in the user's interface to RECON (and to RECON itself).

a. The external network users will not have an interactive interface to RECON. They will only be able to supply fully specified batch queries (or query procedures using the QUERY command).

b. The external network users will not be able to select fields of the RECON record to be returned. Only the entire releasable RECON record will be returned to the external network user.

c. The filter capability (outlined in Appendix B) will be implemented for external network users.

6.5.1 The Need for Batch Access for External Network Users

The reason for eliminating interactive working with RECON for external network users is that there is no way to subject the informational messages generated by RECON to the same checksum test applied to data records because the message contents are dynamic (counts of the number of records, lists of "adjacent" keywords, and the like). If RECON were subverted, these messages could be replaced with unauthorized data for an external user-agent.

There is no safe way to permit such messages. As a consequence, it is concluded that running RECON in batch mode is the only feasible way to circumvent the problem.

The major problem found with error messages is that they are applied dynamically; i.e., as errors are encountered. With very few exceptions however, they do not contain dynamic data. Even in the cases where the error message repeats information (e.g., an accession number, file name), the error message could be recast to be static. Under these conditions, the error messages sent to external users could be checksummed to permit their transmission to external users. Coupled with some additional separate messages such as "OCCURRING IN FIRST COMMAND LINE," "OCCURRING IN SECOND COMMAND LINE," etc. (up to the maximum of 50 command lines RECON can store as a canned query), that can also be checksummed and sent with the substantive error message to help a user localize his error.

(An alternative considered earlier would be to replace the standared RECON error messages with about six generic messages, locate them in the GUARD, and permit RECON to request the transmission of from one to six of them to a designated external user. However, the additional complexity introduced to the GUARD, changes to RECON to map existing error message numbers into one of those approved, and the reduced help provided to users over the simpler changes outlined above have led to the rejection of that approach.)

6.5.2 Implementing "Batch RECON"

The first constraint does not appear to require any functional change to RECON to support. There is a "canned" query capability already built into RECON that could be used to execute a query sequence entered by an external network user. The external user would use the COINS TAS with or without ADAPT to create the RECON query. When the query is formed, he can direct it to RECON just like he now does for other COINS batch applications. The query will be staged in the HAS interfacing RECON to the network.

When RECON accepts a query from the HAS, it passes the query as a canned query (probably in Query execute mode) to the canned query processor. If the filter recommendation is implemented, RECON may attach a filter to the query appropriate to the dissemination authorized to the particular user (or Agency, or group, etc.).

RECON will maintain a user control block for the external network connection(s) that will relate a query to a particular originator.

The exact interface between RECON and the GUARD has not been defined in this study. Whether each single RECON record that satisfies an external query will have the destination address attached and sent to the network, or whether the GUARD will be able to accept groups of records destined for a single user is a function, in part, of the amount of Random Access memory available in the GUARD, as well as whether there will be a requirement for the GUARD and HAS to multiplex responses from RECON in order to maintain throughput. It is sufficient for now to indicate that these issues will have to be resolved at the detailed design level.

6.5.3 Whole RECON Records

The change that delivers only whole RECON records to external network users can be handled administratively (by not telling external network users of the DISPLAY, TYPE, etc.), or by extending the use of the "SECURITY" file to indicate commands not allowed to specified users. This change is only to minimize the complexity of the GUARD. Working in COINS, the external users have editing and storage facilities available to them in the TAS's to provide selection and formatting of various data fields.

6.5.4 Implementing Filters in RECON

Implementing the filter approach outlined in Appendix B offers no particular technical challenge. The filter is important since it relieves the GUARD of having to handle unauthorized records except when there is a failure or error of some kind in the RECON system itself. Thus, the GUARD will act as a check on the correct operation of RECON rather than as a guarantor of its correct operation. This shift in perspective is important in minimizing the complexity of the GUARD.

6.5.5 Bandwidth of Covert Signaling Using Error Messages

By permitting any error messages at all to be returned to a designated user, there is created a covert signaling path from RECON to that user. In the absence of any additional constraints, it would be possible for a subverted RECON to pass the content of unauthorized RECON records to an external user as a binary stream merely by adopting the convention that one error message stands for a binary 1, and some other error message stands for a binary 0.

Since the method recommended of generating checksums for all error messages along with a number of messages to help localize errors is designed to permit virtually arbitrary error messages to be returned to external users, there is no way for the GUARD to easily determine whether the messages being passed are legitimate or signals without increasing the awareness of the GUARD about its environment and, incidentally, increasing its complexity.

To determine the covert signaling rate if RECON were connected to COINS, measurements were made of the actual time to send messages of various lengths between two processes in different access systems. The measurements were taken under normal operating conditions in that both access systems were actively supporting normal network operations. These measurements approximate the signaling rate that would be available between RECON through its HAS to a process (file) on another TAS in the network.

The results of this quick study are shown in Table 1.

Message Length in Characters	Effective Character Transmission Rate (Char./Sec.)	Covert Signaling Rate Bits/Sec. (Err. Msg. = 100 Char.)
100	8.5	.085
1982	150	1.5
31777	1000	10.0

Effective Data Transmission Rates Between
Access Systems

Table 1

While the table shows the effects of a relatively high fixed overhead to handle network and I/O protocols, what is of interest to us is the expected covert signaling rates under the assumption that the error messages will be 100 characters long (or shorter).

Since COINS does not accumulate traffic for a specific destination but rather forwards messages as received, the .085 bits/sec. covert signaling rate is on the order of what one could expect if the RECON error messages were used to encode unauthorized information. At this rate, a 300-character record would take approximately 7.8 hours to transmit.

Any further reduction(s) will require incorporating an error message rate detector in the GUARD to raise an alarm if error messages are being sent more frequently than a specified rate.

6.6 Extensions of the Authenticated Releasability Concept

6.6.1 Summary of Key Notions

The principal conceptual notion of the proposal outlined in this paper is the fact that the design of the GUARD is predicated on the concept of checking on the correct operation of the guarded resource. The GUARD is not made an integral part of the application. Because of this simplicity, it becomes easy to extend the concept to more realistic conditions than twice postulated at the beginning of this section to explain the concept.

6.6.2 Handling Multiple Protected Categories

In Figure 4, we represent the approach outlined in section 6.2. There is the superset A, corresponding to all RECON records, and the subset B, corresponding to those which can be released to external network users. The users of the system correspond to these two sets. There is no GUARD processor intervening between RECON and the users authorized access to all

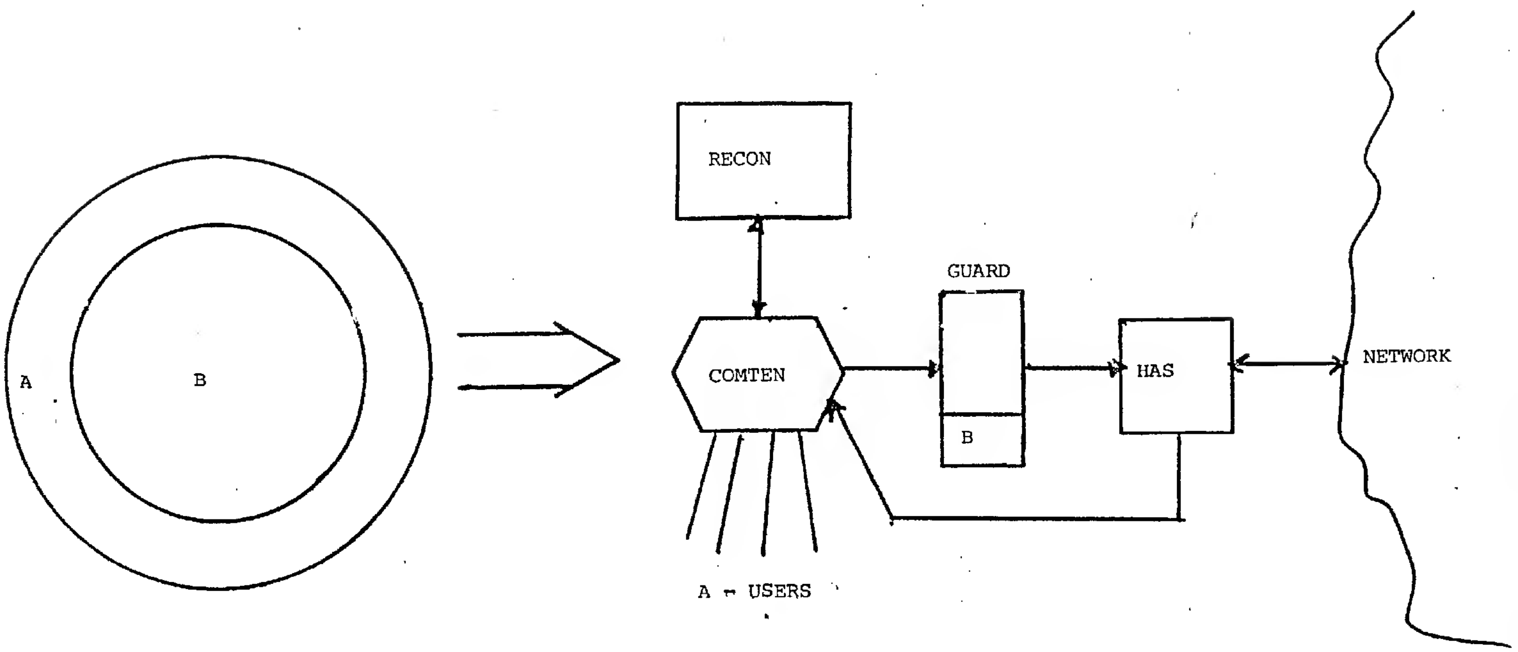


Figure 4

Symbolic Representation of Basic Capability of the data base because it is not required. Symbolically, the key associated with the materials releasable by the GUARD is shown in the block representing that function.

In this section, we will show symbolically how various protection configurations can be handled by straightforward extension of the GUARD concept.

Figure 5 shows the arrangement of two (or more) disjoint categories (for a far-fetched example, limiting NSA access to just NSA-produced items, DIA to just DIA-produced items, etc.).

The role of the GUARD is still to check on the correct operation of RECON, which is supposed to route B category material to the B-GUARD and the C category material to the C-GUARD. The dotted end-to-end crypto boxes shown are optional depending on the degree of trust the various groups have in the correct functioning of the network. If the groups must protect <u>their</u> material from possible misroute to another, then the end-to-end crypto function will provide that protection. Note, however, that in the COINS network, the network is protected by full-period crypto on all links. The only protection that the end-to-end crypto would provide is against possible misaddressing in the HAS or misrouting in the COINS imps.

The categories B and C are distinguished on input in some fashion (in this example, by Agency of Origin), and the checksum computed for a record is keyed based on the information distinguishing the records. That is, B records are checksummed using the B key and C records are checksummed using the C key. The generation of the input checksums is not shown in the figures.

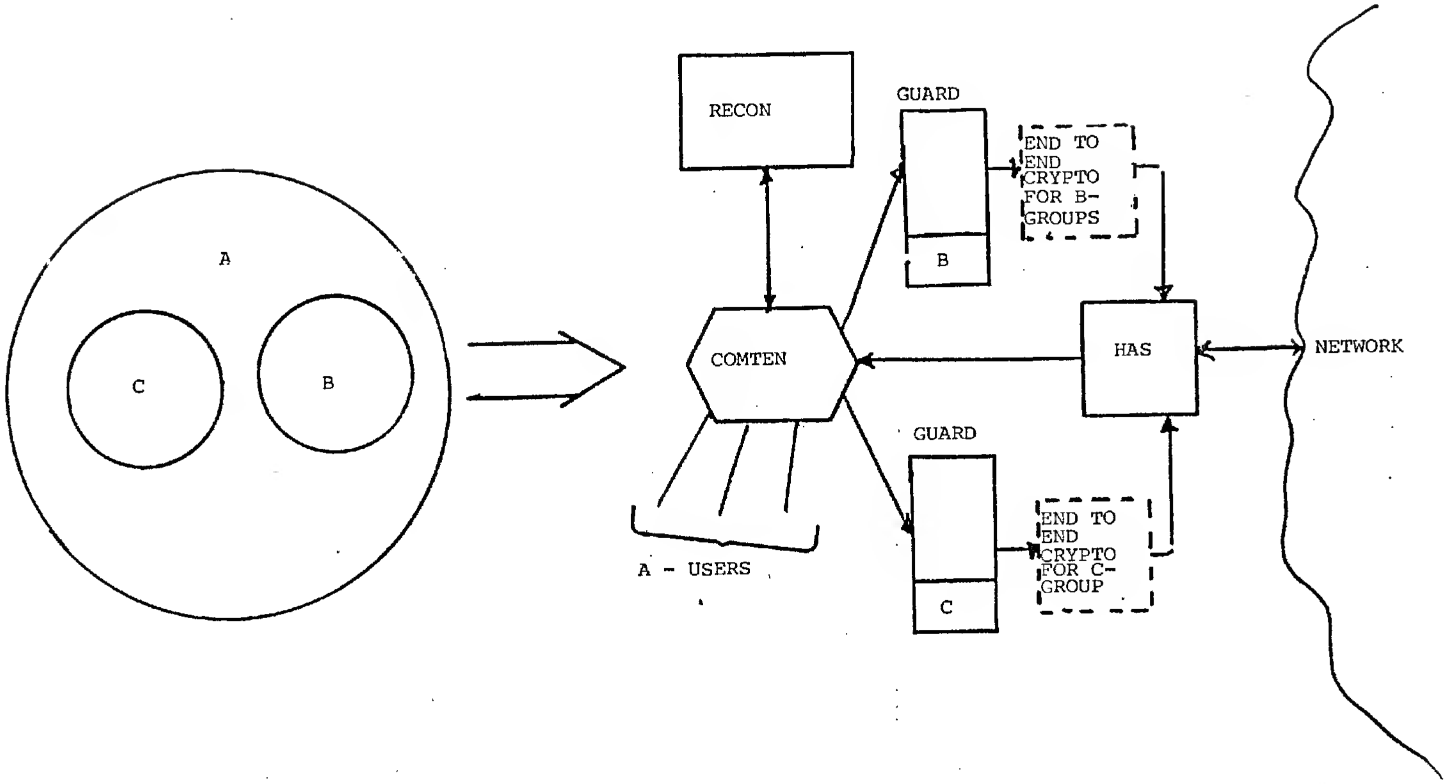


Figure 5

Two or More (Disjoint) Categories

The GUARD's are shown as separate boxes, one for each group or Community of interest involved. The cost of the GUARD is expected to be small enough that for application to the RECON-COINS case there can be a GUARD for each category (group of users).

One can imagine attempting to put all of the GUARD function in a single machine, using a group indicator of some kind to instruct the GUARD to select the appropriate key to farm the checksum, and if it checks, route the record through the appropriate end-to-end crypto function as shown in Figure 6. However, this raises the level of complexity of the GUARD by requiring it to discriminate correctly among the various categories and to not only perform the checksum correctly but to select the proper end-to-end channel as well. If the costs permit it, separate GUARD's are preferred.

Figure 7 shows the arrangement where two or more categories are involved with a superset shared. This form illustrates an arrangement that could give an Agency unrestricted access to the generally releasable material (B), as well as access to ORCON material produced by the Agencv (group) making the request (e.g., C).

The degree of control this arrangement provides for ORCON material is a function of how fine a discrimination is possible among originating groups or Agencies. For instance, if the discriminant is based on Agency of Origin (e.g., DIA) and the fact that it is ORCON material, then it is possible to respond to requests from DIA and return all general records and DIA's (only) ORCON records. If DIA or the sponsor needs to break the access down further, it is necessary to further qualify the Agency of Origin (in this case) (e.g., DIA-MS4 or DIA-MS1) in order to select the correct checksum key when the record is entered into the system.

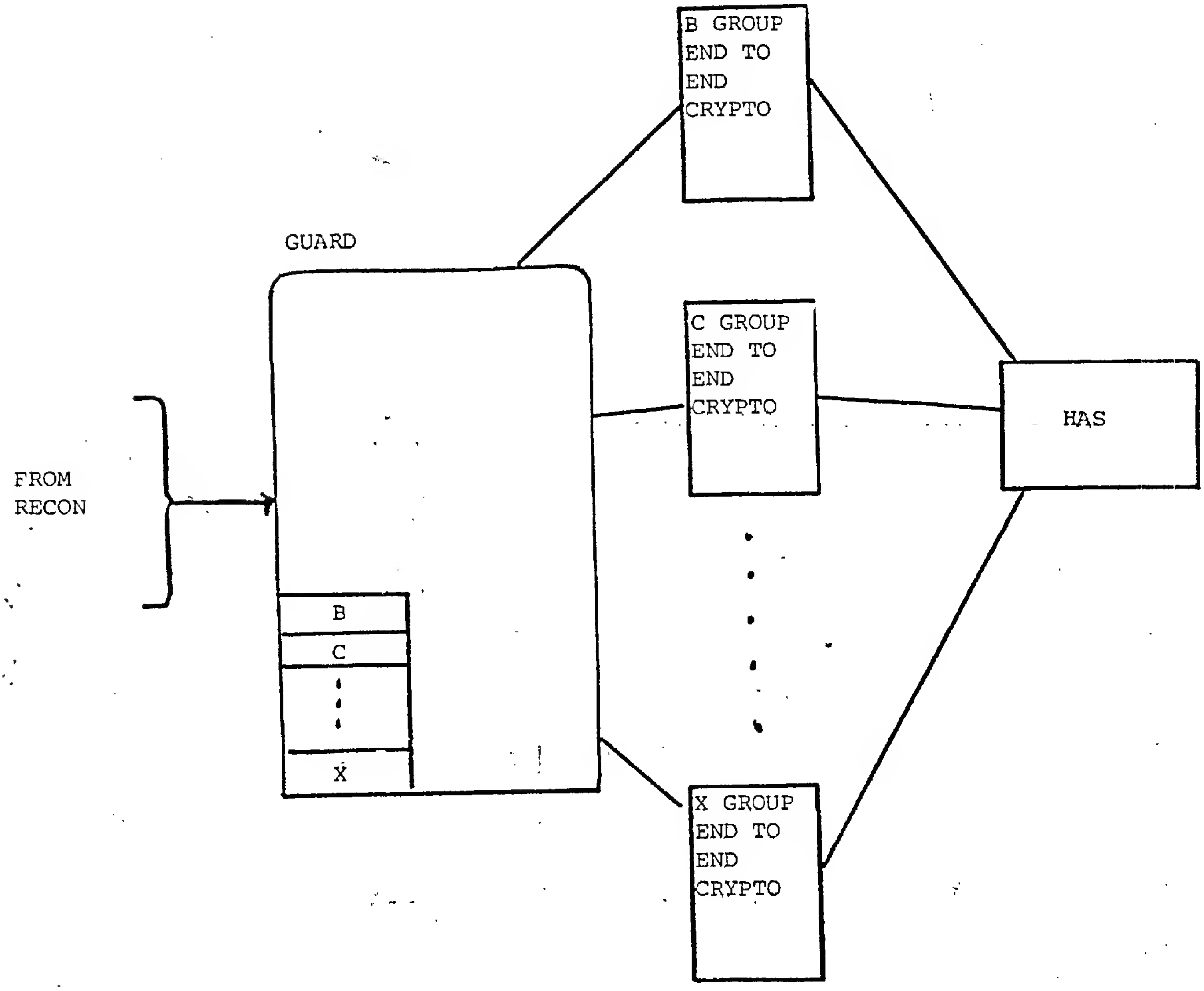

B GROUP END TO END CRYPTO
GUARD
C GROUP END TO END CRYPTO
HAS
FROM RECON
B
C
X
X GROUP END TO END CRYPTO

Figure 6

Consolidated Guard Functions

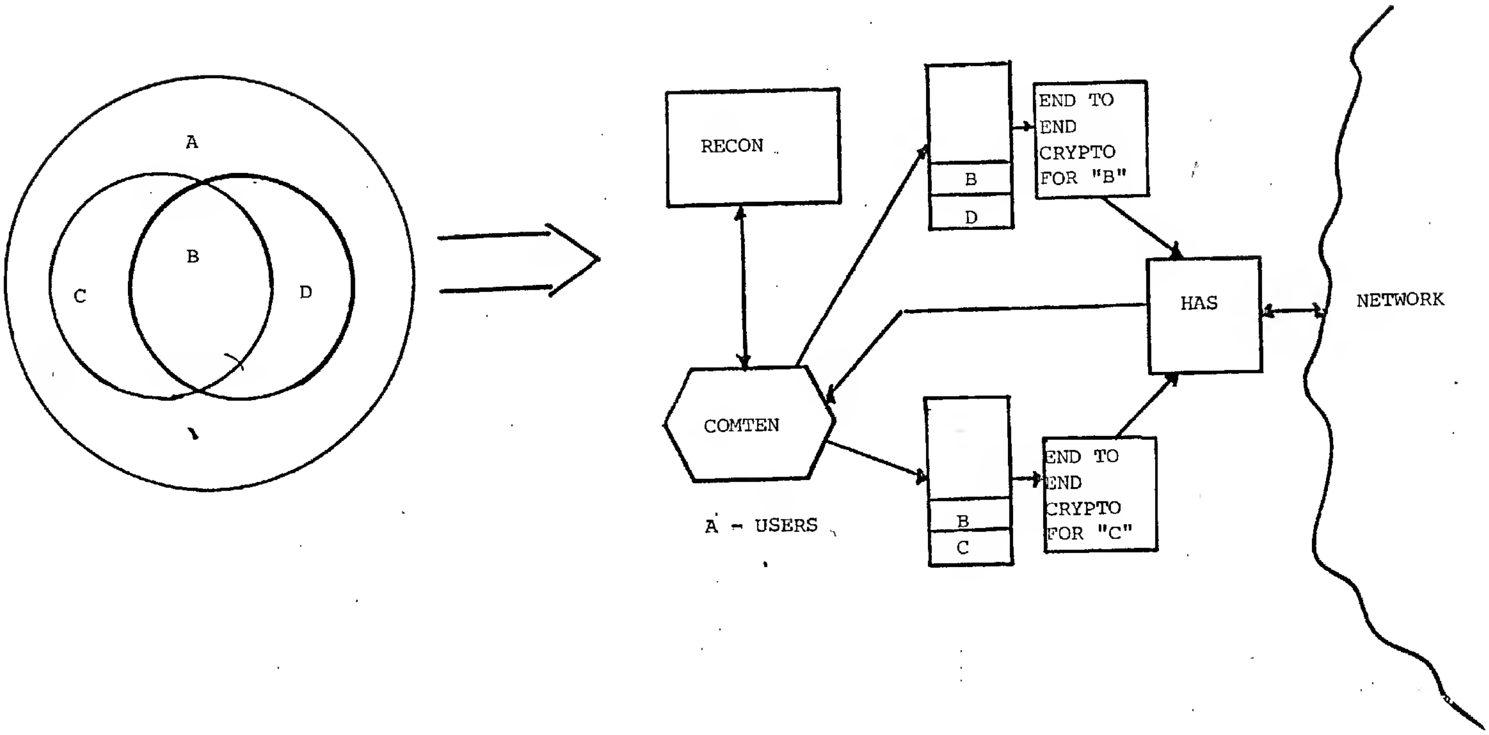


Figure 7

Controlling Access to Two or More Groups (Compartmentation)

Thus, each record in the system would still have a single checksum, the key for which is a function of the Agency of Origin only for otherwise restricted distribution material. That is, if the record being entered into RECON is generally releasable (based on classification, dissemination, and codeword values), it is checksummed using the B key (in the diagram). If the record being entered requires restricted distribution based on the classification, etc., but would be releasable to the Agency or group that originated it, it would be checksummed using the appropriate key (e.g., C).

All queries from external users are filtered as suggested in section 5.3. Ordinary external users would have a filter that permits access to B records only. Extended access users would have filters that permit access to B or C records, or B or D records, etc.

To get the appropriate (allowed) record set past the GUARD processor, checking the releasability will require a small change to the GUARD's functionality. In the previous examples, if the recomputed checksum did not match, the record was not transmitted and an alarm raised. In the present case, the GUARD is provided with a set of keys corresponding to the access categories permitted to the users associated with that GUARD. The GUARD computes the checksum with each key in turn until either an exact match is found or all keys have been tried. If all keys have been tried and no match results, the record is not transmitted and an alarm is raised.

Finally, Figure 8 shows how the scheme could be used to control dissemination based on the hierarchical classification scheme of Top Secret, Secret, Confidential, and Unclassified. This example is not shown in the context of RECON and COINS because COINS runs in a System-High mode and is

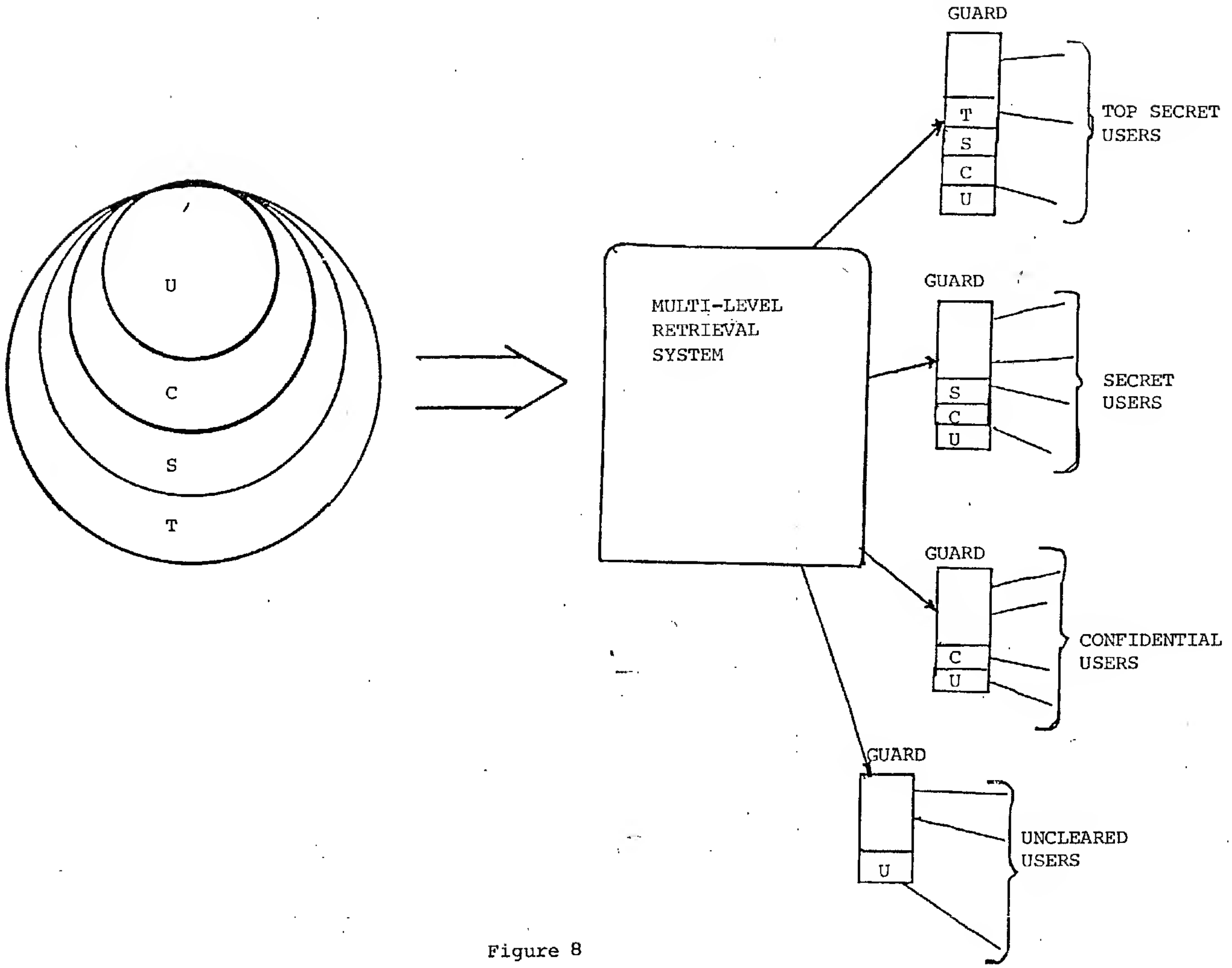


Figure 8

Controlling Hierarchical Dissemination

provided merely to illustrate the potential this technique has.

Here, records entering the retrieval system are checksummed with a key which is selected based on the classification of the record. Requests against the data base are filtered based on the clearance of the requestor. Thus, Top Secret users would be able to retrieve everything, while Uncleared users would be able to retrieve only Unclassified records.

As in the previous example, the GUARD's compute checksums until a match is found or all keys have been used.

This case raises a performance question that was not a factor in the earlier examples. In particular, if the GUARD would have to compute checksums through all stored keys until a match was found, it could reduce the throughput of the GUARD significantly. There are two possible approaches to this problem depending on its severity. First and simplest, the keys could be arranged in GUARD's in order of expected frequency of occurrence. Thus, if 80% of the data base is Unclassified, 10% Confidential, 8% Secret, and 2% Top Secret, the keys would be placed in the GUARD's so the Unclassified key was used first, then the Confidential key, and so forth.

If the checksum function really becomes a bottleneck in this mode of operation, it would be possible to compute two or more checksums in parallel by merely supplying additional DES cards. If the number of DES cards were less than the total number of checksums that had to be computed, the control for the additional parallel operation would be complicated slightly. However, it is not expected that it would be very difficult to design.

7. OPERATIONAL IMPACT

7.1 RECON Operations

The degree of operational impact this approach will have depends on how much the present automated hold file and RECON preprocessor are trusted to correctly extract classification, codewords, and dissemination codes from incoming electrical traffic.

RECON now operates this way with no problems mentioned. If the software which attaches these labels is trusted to do so properly, then a program can read the labels and divert the traffic into one or more (depending on the number of categories involved) subfiles for later computation of the input checksum. If such an arrangement is acceptable, then the impact on RECON indexing operations is nil, since RECON records will be handled by OCR personnel in exactly the same way they are now.

If all records are checksummed with a key appropriate to their releasability (i.e., releasable to network users, releasable only to sponsor personnel, etc.), and the checksum generator is placed in the RCC network as indicated in Figure 9, then if the checksum generator remains a dedicated single-function machine as described in the previous section, it could be programmed to automatically analyze the codeword, classification, and dissemination codes of each record, and select a key appropriate to the dissemination policy implied by the combination of values.

This arrangement depends critically only on the correct analysis and assignment of the classification, codeword, and dissemination codes for each record. If such assignments can be made correctly (as they apparently

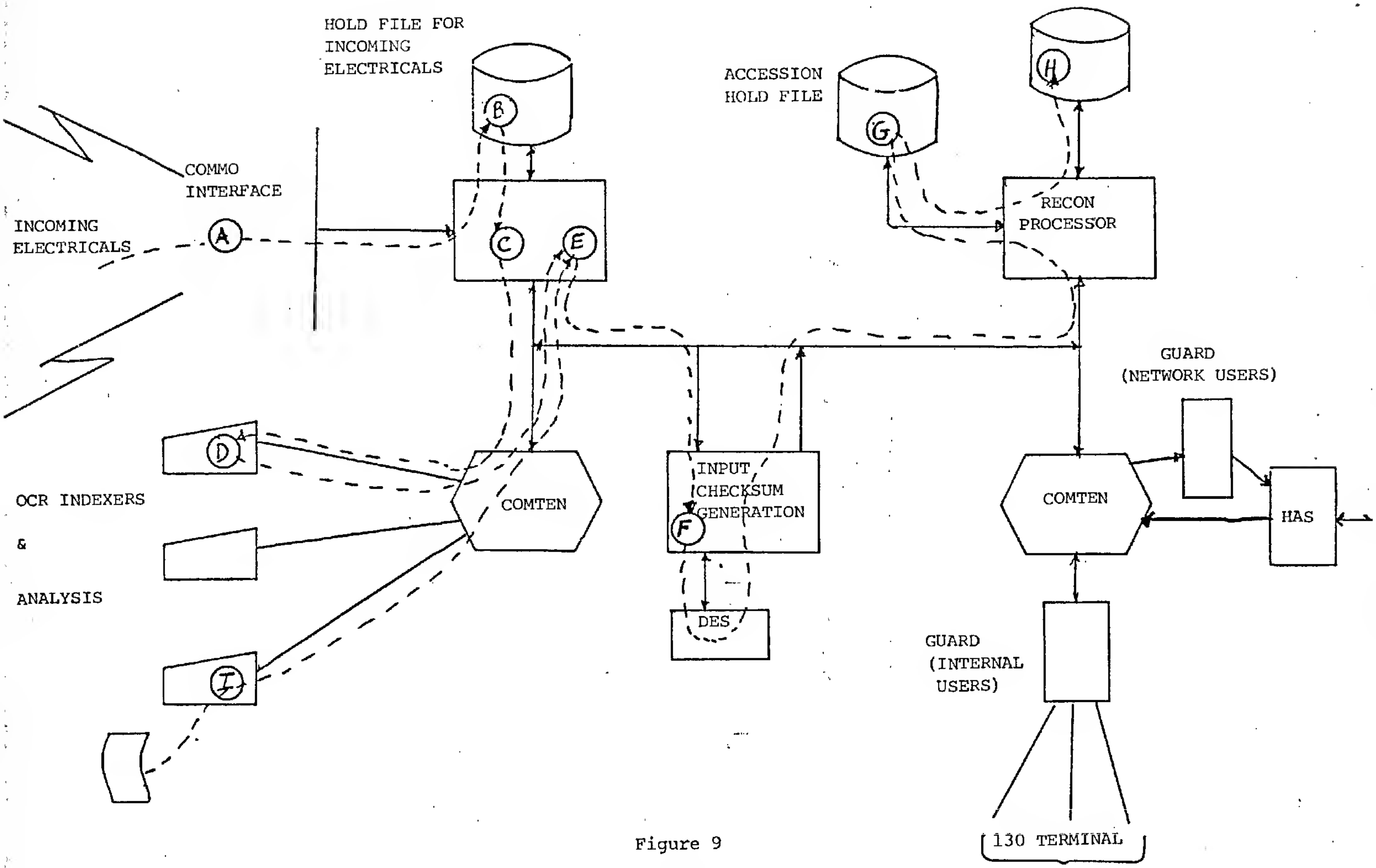


Figure 9

A Possible Configuration of Guards and Checksum Generators
to Minimize Impact of RECON Operations
Showing Flow of Data

are now), then the checksum generator and GUARD's can meet the protection objectives of the sponsor.

The data flows of the diagram are:

A. Incoming messages are processed by COMMO and released to the RCC network to be processed for RECON.

B. The incoming data is held in a buffer file for processing by OCR indexing personnel.

C. Prior to indexing, the message is scanned and a RECON record is partially filled out. The classification, codeword, and dissemination codes are entered in the skeleton record.

D. The skeleton RECON record is processed by the OCR analyst and subject codes, etc., are coded as the situation requires.

E. The record is released by the OCR analyst for routing to the checksum generator.

F. The record is released to the checksum generator where the classification, codeword, and dissemination codes are analyzed to select the proper checksum key.

G. The checksummed record is placed in a hold file.

H. The RECON data base is updated with the records in the accession hold file.

I. A RECON record is keyed in directly (from first principles) by an OCR analyst. It is routed to E., from which it follows the steps outlined above.

Note that if the checksum generator is bypassed by the RECON records processor, the affected records will not ever be released to either internal or external users.

7.2 Increased Data Storage

The checksum is eight bytes long. If the average size of a record is 150 characters or so, this will add about 5% to the storage required. If all 3.5 million RECON records currently had checksums, the total storage increase would be about 28 million bytes, or about 10% of a 3,350 disk.

REFERENCES AND BIBLIOGRAPHY

1. AND80 An Approach to Solving the RECON Security Problem,
STAT [redacted]
1 November 1980

2. KIN80 The <sponsor's> RECON System as a COINS Host,
STAT [redacted]
3 March 1980

3. REC80 RECON IV, An ON-LINE Intelligence Information Retrieval
System USERS Manual,
NFAC OCR/SSD
April 1980

4. WOO79 Applications for Multi-Level Secure Operating Systems,
STAT [redacted]
1979 AFIPS Proceedings, pp. 319-328

APPENDIX A

COINS SECURITY SUMMARY

INTRODUCTION

Much of the present COINS access control functionality is placed in COINS Access Systems (CAS's). This appendix outlines the CAS security architecture, with the exposition being given in terms of a Terminal Access System (TAS). It should be noted that the security functions described for the TAS are available for the other CAS's as well.

The TAS architecture is responsive to the diverse and dynamic nature of the COINS network. It provides a coherent interface to server-host computers of different manufacture and to data base applications of widely varying design. It was conceived of as a means of insulating its users from much of the differences that exist in the different server-host systems and the data base query languages.

The TAS security architecture has been designed to provide maximum protection to the sensitive data in the network while keeping the end-user's interface as simple as possible.

In addition, the TAS security architecture has addressed the problem of security administration. It provides the user organizations with considerable flexibility in how the security is managed. It also allows a single TAS to support more than one organization, each of which can exercise full control over their own security management, yet be isolated from and non-interfering with other co-resident user organizations.

Specific security features of the TAS are discussed below.

1. Structured Network Identifiers (SNI)

All TAS users are uniquely identified with an 8-character identifier of the form:

TAAGGUUU

where:

T is the user's home TAS.

AA is an Agency designator representing the user's agency.

GG is a group within an Agency.

UUU is the user within the group.

The structured identifier uniquely identifies all COINS users entering through TAS and permits both activity and security logging of an individual's network activity. A user requires an SNI and a password to logon to a TAS.

2. Access Authorization

Each user known to a TAS (i.e., who has an SNI) has an access authorization record in the Access Authorization (AA) file. The record contains the following basic information:

a) User's name

b) Clearance level

c) Logon (to TAS) password

d) SSN

e) Agency identification

f) Organization within Agency

g) Address

h) Telephone number

i) User type (student, crisis, operational)

j) Compartments (other than SI or TK which are included as part of the clearance data)

In addition, the record contains a list of the COINS applications (e.g., RYETIP, SOLIS, DIAOLS, ADCOM, etc.) and for those applications that provide files, a list of files authorized to the user by the user's home organization.

If the application is interactive (SOLIS, NDS), the user's access authorization record contains the interactive system logon information in the form required by the interactive system. This usually includes an identifier and password. The information is used to perform a user-invisible logon to the server-host supporting an interactive application. This "surrogate logon" service of TAS insulates COINS end-users from the considerable variability in logon protocols from one kind of computer system to another.

Application and file access controls are applied to terminals as well. Each terminal connected to TAS is logically identified by TAS and has an AA record defining which applications and files within the applications may be accessed by the terminal.

A "session security level" is logically established based on the user's authorization and his terminal's authorizations. This (conceptual) level controls what data may be accessed in a session.

The user and terminal AA files are used by TAS to implement the major functions of TMA-3:

- Control of user access to a data base.
- Verification that a user/terminal is cleared to receive a batch response.

As will be seen in a later section, the AA files and the TAS security architecture are expected to play increasingly important roles in further extending COINS services to the Community.

3. Server-Host Access Authorization

When TAS was upgraded from a user-host to include server-host functions in 1978, the access authorization function was expanded to include application access authorization data.

Interactive or batch applications hosted or front-ended by a particular TAS or HAS are registered in an access authorization file on that TAS or HAS. The access authorization file contains for each application a list of terminals and user's identifiers (SNI) and passwords authorized to access the particular application. Terminals are identified by a host-id/terminal-id combination (i.e., from what Agency an access is attempted). Within an application, the user's type of access (retrieve or update) can be restricted to specific files.

4. Decentralized Security Management

The TAS security management design was influenced by the following major considerations:

a) Each using Agency would be responsible for managing the security information and access authorizations of its own users.

b) A large using Agency may wish to delegate some of the security management to functional organizations within the Agency.

c) A single TAS may be shared by two or more independent Agencies.

To meet these somewhat diverse requirements, the TAS security architecture includes three kinds of users:

TASMASTER — A single user who "owns" the TAS and creates and directly or indirectly (see Administrative User) creates all other users.

Administrative User — A user who has the delegated authority to create and administer a specified set of ordinary users.

Ordinary Users — Users authorized to use TAS and the COINS network.

An Administrative User can add, modify, or delete users within the group that can be "named" with the same single "SNI-prefix" as assigned to the Administrative User. That is, the up to 1,000 users who have the same

TAAGG (TAS, Agency, group within the Agency) prefix in their SNI.

Administrative Users CANNOT affect any records other than those belonging to them.

The TASMASTER establishes the basic access authorizations for Administrative Users. The Administrative User can further subdivide his access authorizations among users within his domain. He cannot give any user more privileges than he has himself. It is not required to give an Administrative User ALL TAS or network privileges.

APPENDIX B

ADDING FILTERS TO RECON

The classification, codeword, and dissemination codes of the RECON records can be used in combination to identify material that is not to be released to external (i.e., COINS or other) users. This fact can be used to (invisibly to the user) apply a filter consisting of a series of AND NOT < dissemination codes and codeword codes > to each (implied) SEARCH command issued by a user to exclude restricted material from the search.

In general, the RECON implied SEARCH command produces a set of records that meet the specified search criteria. The result sets are associated with a user's work space and can be combined or limited in various ways after a search has taken place. It is possible to combine the results in two or more sets through logical operations (e.g., one can create a set on [redacted](1) and another set on [redacted] (2), then logically combine the sets 1 AND 2 instead of having to specify that intention in the initial search as [redacted].

STAT STAT STAT

Because of the ability to manipulate sets to create combined sets which may then be edited to print records or any selected fields, it is necessary for the filter to be applied at the point where the total request is essentially satisfied. Since it is expected that external users of RECON will only be entering batch queries, the filter should be applied just before the output set is to be transmitted to the requestor.

Mechanics

The mechanics of using the filter approach to limit access to parts of the RECON data base involves the following three steps:

a) Recognizing external users.

b) Identification of the appropriate filter.

c) How (when) to apply the filter.

Each of these elements will be discussed below.

Recognizing External Users and Identification of Filters

This is as simple as setting a single bit in the user's logon identification record to identify that the specified user is to have restricted access to the file(s) that he is authorized to search. A one-byte designator of which filter is to be applied to this user whould be more than adequate for the foreseeable future.*

These two pieces of information will have to be included in the user control block established as part of the session. (The exact sponsor's jargon for this control block is not known; it is the data kept by RECON during a session that identifies the user, his terminal address, and holds the threads to his workspace and files.)

Above, the filter was described as a series of AND NOT < restricted dissemination codes > . It would also be possible to define the filter as

*This model is predicated on each user, by name, being registered in the RECON data base. A less burdensome (to RECON) approach would be to register by name only those external users who are granted extended access (perhaps to ORCON material) and treat the rest of the user opopulation by generic names (e.g., NSAUSER, DIAUSER, STATEUSER). The most restrictive filter would apply to the generic users.

AND < permitted dissemination codes > . Which form is better is a function of which would lead to the smaller specification.

How (When) to Apply the Filter

The best way to apply the filter would be to prespecify the set corresponding to the filter and then apply that set invisibly to the set that is generated by the user's operand specifications. Thus, in the hypothetical example:

STAT

[redacted] would result in:

SET NO.	NO. RECORDS	NO. OCC.	DESCRIPTION OF SET
n	25	25	[redacted]
n+1	60	60	[redacted]
n+2	15	15	n AND n+1 (AND NOT FF)

STAT

where FF is an invisible set number used to identify the prespecified filter set.

The mechanics of applying a filter are relatively straightforward. Whenever an output command is activated, it tests the bit in the user control block to see if this is a user to whom a filter is to be applied. If the test passes, the command extracts the one-byte filter-id and then takes an EXIT EXIT that allows it to apply the filter before returning to continue the normal output processing for external users.

Summary

This appendix has outlined a method of restricting access to RECON records based on the dissemination and compartment codes assigned to the records at their type of creation. The technique provides as much control as desired based on labels assigned to the records. The modifications required of RECON to accommodate these additional controls are minimal (probably less than one-half a man-year of one of the system programmers maintaining the application).

Adding filters to RECON is a necessary adjunct to making RECON available to the Community if the simplicity of the GUARD is to be maintained.

APPENDIX C

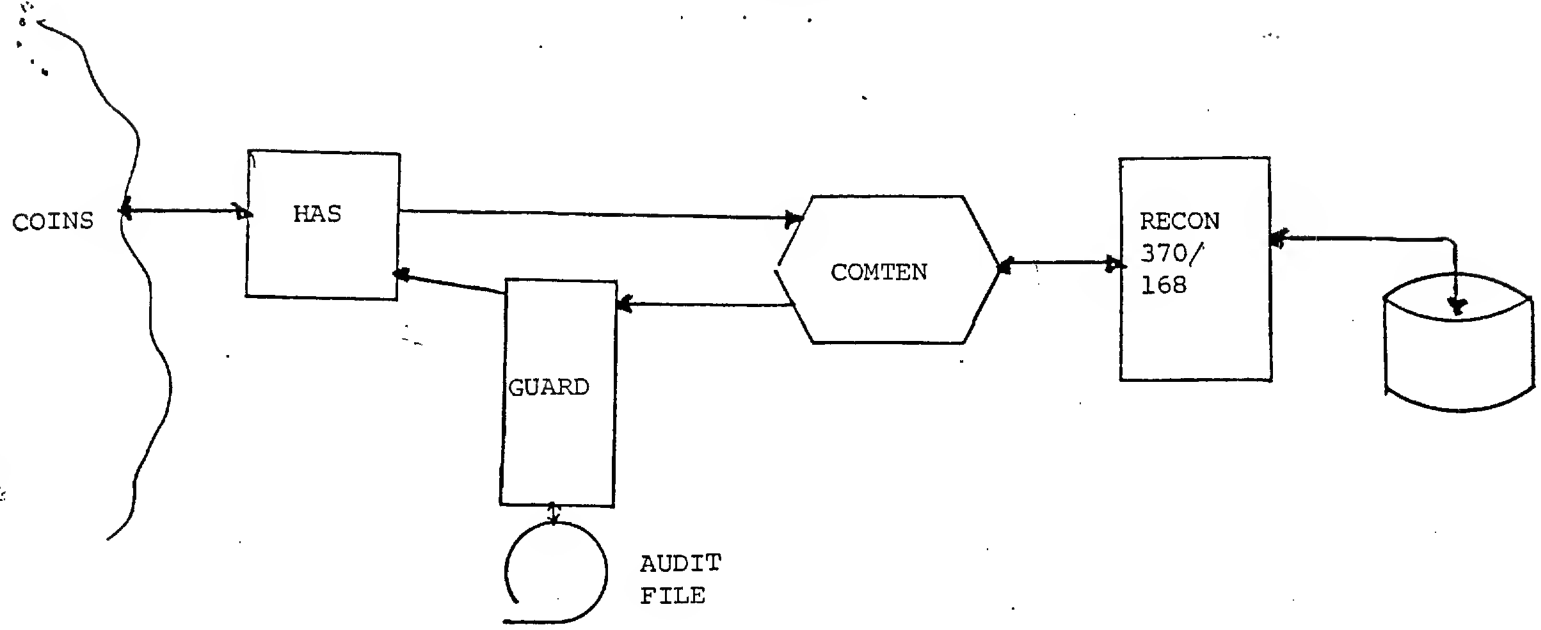
GUARD IMPLEMENTATION EXAMPLE

Configuration

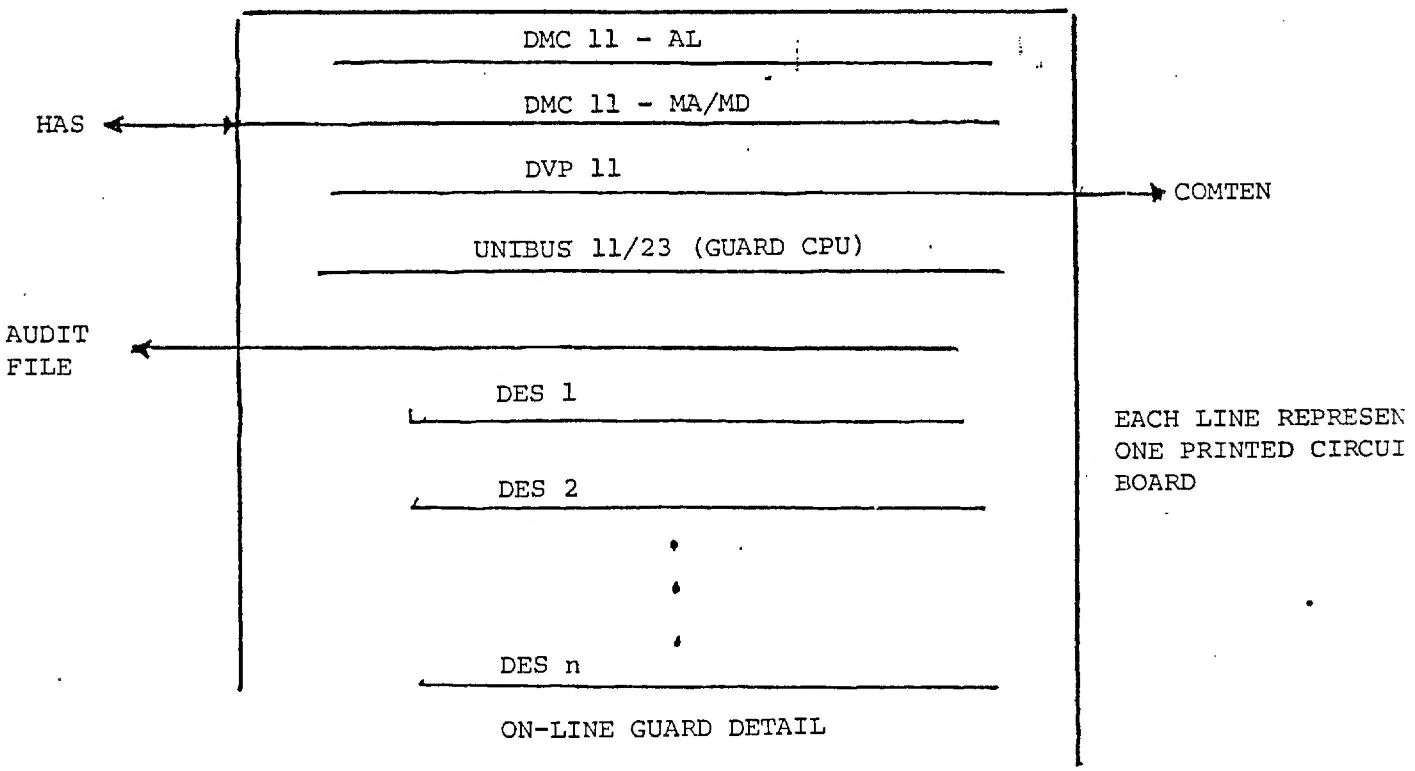
The basic components of the on-line GUARD device, Figure 10, and the update GUARD device, Figure 11, which implement the cryptographic checksum function(s) are the UNIBUS-compatible 11/23 CPU and the "n" DES1100DSM printed circuit boards (PCB's). The other PCB's shown in the diagrams are used to implement the I/O and communications function for the GUARD device. The cryptographic checksum functions are critical. The components of the checksum subsection must operate correctly.

The configuration shown allows the on-line GUARD to handle multiple compartments (categories of releasability). The number of categories a GUARD device can handle is determined by how many DES1100DSM modules can be attached to the 11/23. Each DES1100DSM, operating under a separate (possibly hard-wired) key increases the problems and increases the complexity of a key management system. The categories handled by a single GUARD device can be altered by simply replacing/exchanging DES1100DSM PCB's. The GUARD device could fit within one DEC rack if constructed as indicated above.

The update GUARD device could generate "n" separate checksums by use of the Delta Data 7260 or Delta 5000 function keys. The function keys would be used to select one of the "n" DES1100DSM modules to calculate the cryptographic checksum for a given RECON record.



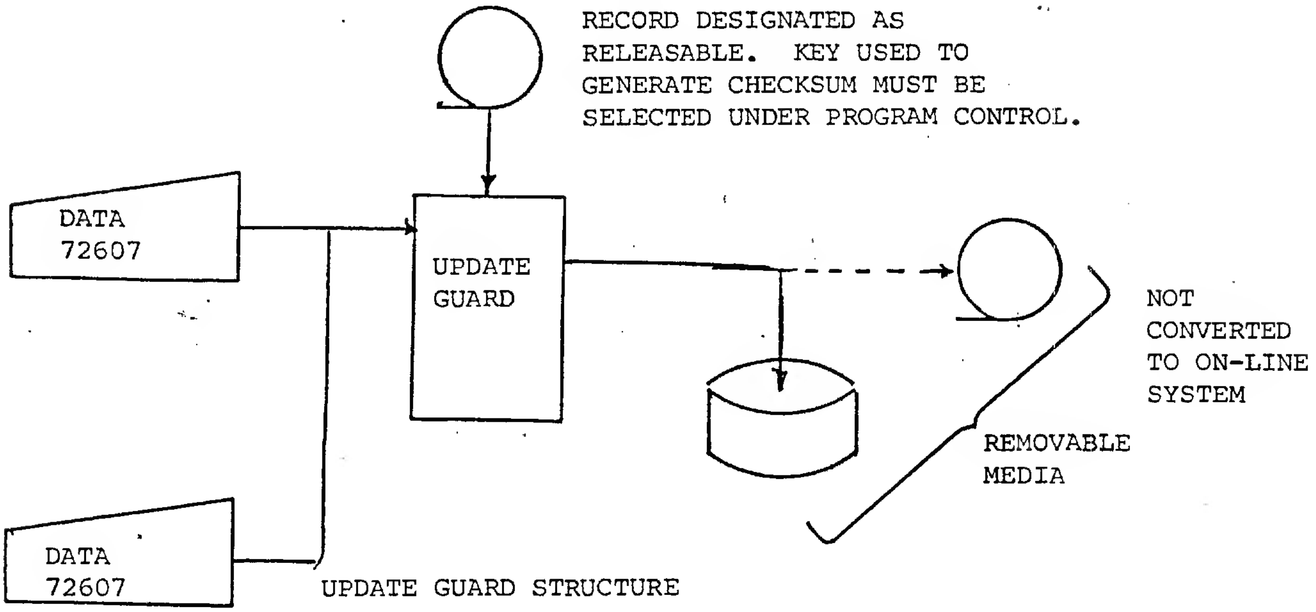
On Line Guard Device Structure



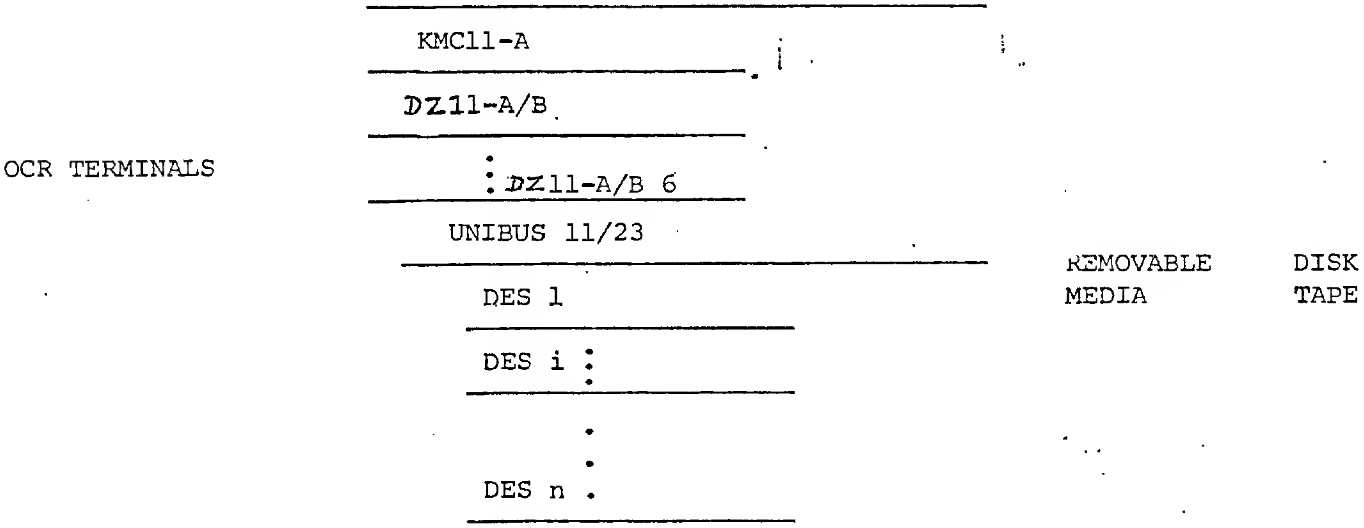
ON-LINE GUARD DETAIL

Figure 10

On-Line Guard



UPDATE GUARD STRUCTURE



UPDATE GUARD DETAIL

NOTE: The COMM IOP-n2 is an asynchronous DMA line controller. It consists of a KMC11-A auxiliary processor and up to six DZ11 asynchronous multiplexers. The DZ11 modules can each handle eight communications lines. The DMA capability relieves the update Guard CPU of the burdensome line handling functions. Flexibility and expandability are inherent in the configurations shown.

Figure 11

Update Guard

The number "n" of theoretically possible categories (compartments) that could be handled with this approach is a function of the DES modules used. The DES1100DSM is suitable for UNIBUS addresses 760000 through 777770 (octal). The DSM requires three contiguous 16-bit buffers. Thus, in the address range above, 2,728 three-word blocks are available. Obvious limitations on space, power, and I/O requirements will reduce the number of DSM's one UNIBUS can handle. However, each GUARD processor can obviously handle many categories.

Functional Description

The concept of operation is simple. As illustrated in Figure 12, the on-line GUARD device, monitoring a given channel, would contain DES1100DSM PCB's for each dissemination category designated for that channel. For a RECON record slated for output, the cryptographic checksum would be recomputed in parallel. If a match occurs with the checksum stored with the record, the data is transmitted.

This approach allows multiple categories with a single checksum field attached to each releasable RECON record. Non-releasable records would contain a blank or null checksum.

The use of the null checksum will standardize the data base structure. Dynamic data base update is then possible. However, all releasable records must have their checksums generated off-line by the update GUARD device.

This can be achieved by an additional off-peak-time procedure. Since all automatic changes to the data base will have null checksums and are thus not releasable, the following procedure could be used:

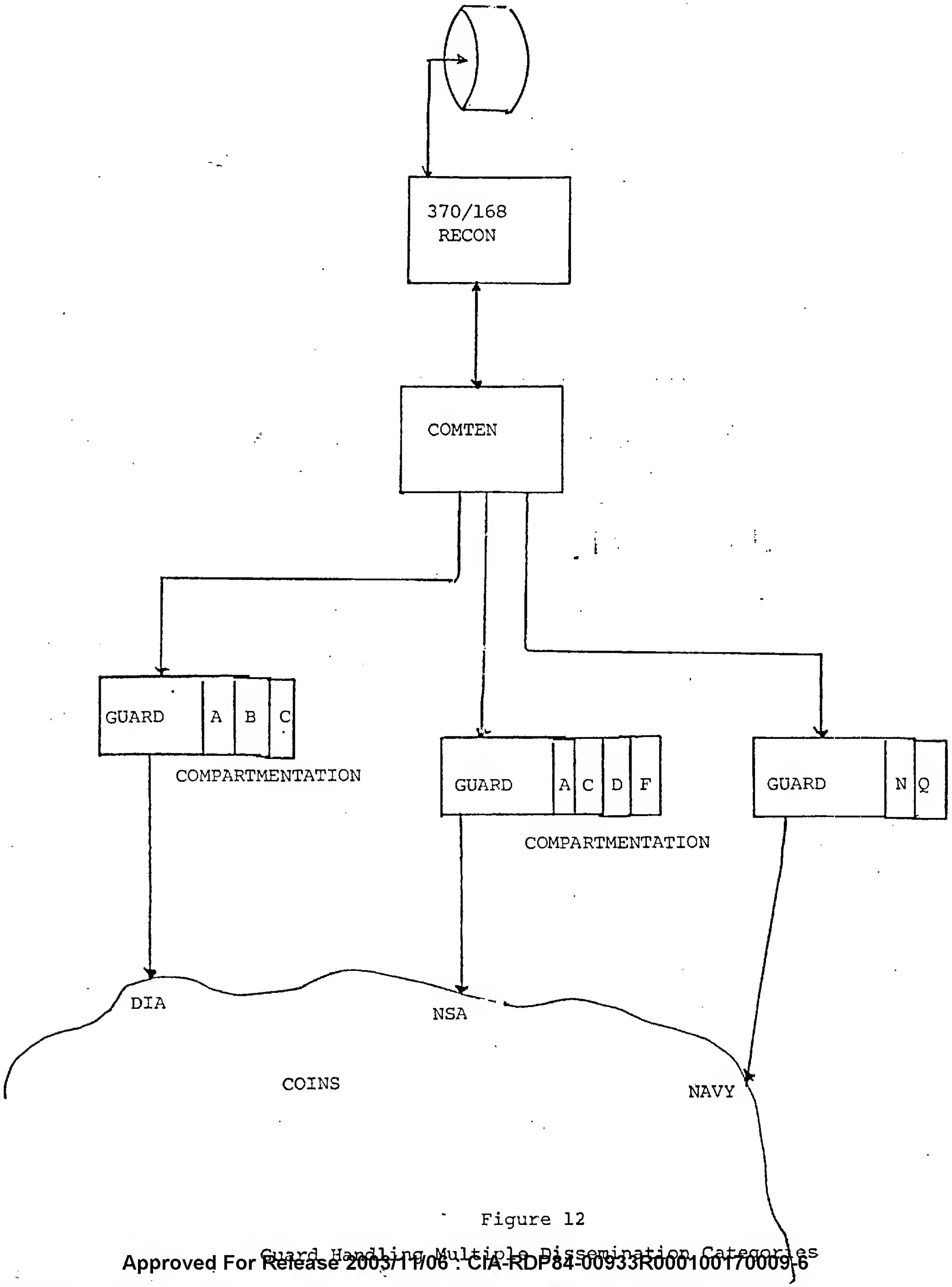


Figure 12

Guard Handling Multiple Dissemination Categories

1. All dynamically entered releasable records are extracted from the RECON data base at off-peak hours and stored on tape or removable disk packs.

2. The tape/disk containing the null checksummed releasable records is passed through the off-line checksum generator process of the update GUARD device.

3. The resultant output of RECON records with active checksums is then merged with the RECON data base during normal update.

The procedure for records entered via the Delta Data terminals would be identical to steps 2. and 3., above. The update GUARD device will accept input from the Delta Data terminals and the peripheral device containing the null checksummed releasable records from the RECON data base. The checksum subsection of the GUARD device is standard for each GUARD application (update or on-line).

APPENDIX D

APPLICATION OF GUARD TO SAFE

The GUARD device approach is applicable to controlled dissemination in the SAFE system. The checksum subsection (UNIBUS 11/23 CPU, and "n" DES1100DSM's) would be unchanged. The peripheral interface of the GUARD would be structured to interface with the SAFE Processor Interface Units (PIU's) and/or Network Adaptors (NA's) instead of the COINS HAS computer. The PIU's provide the interface to the Hyperchannel (WBC). The NA's provide the interface to the Inter-Computer Channel (ICC). The diagram, Figure 13, illustrates a simple example of a SAFE connection. Figure 14 shows the detail for a SAFE GUARD WBC connection.

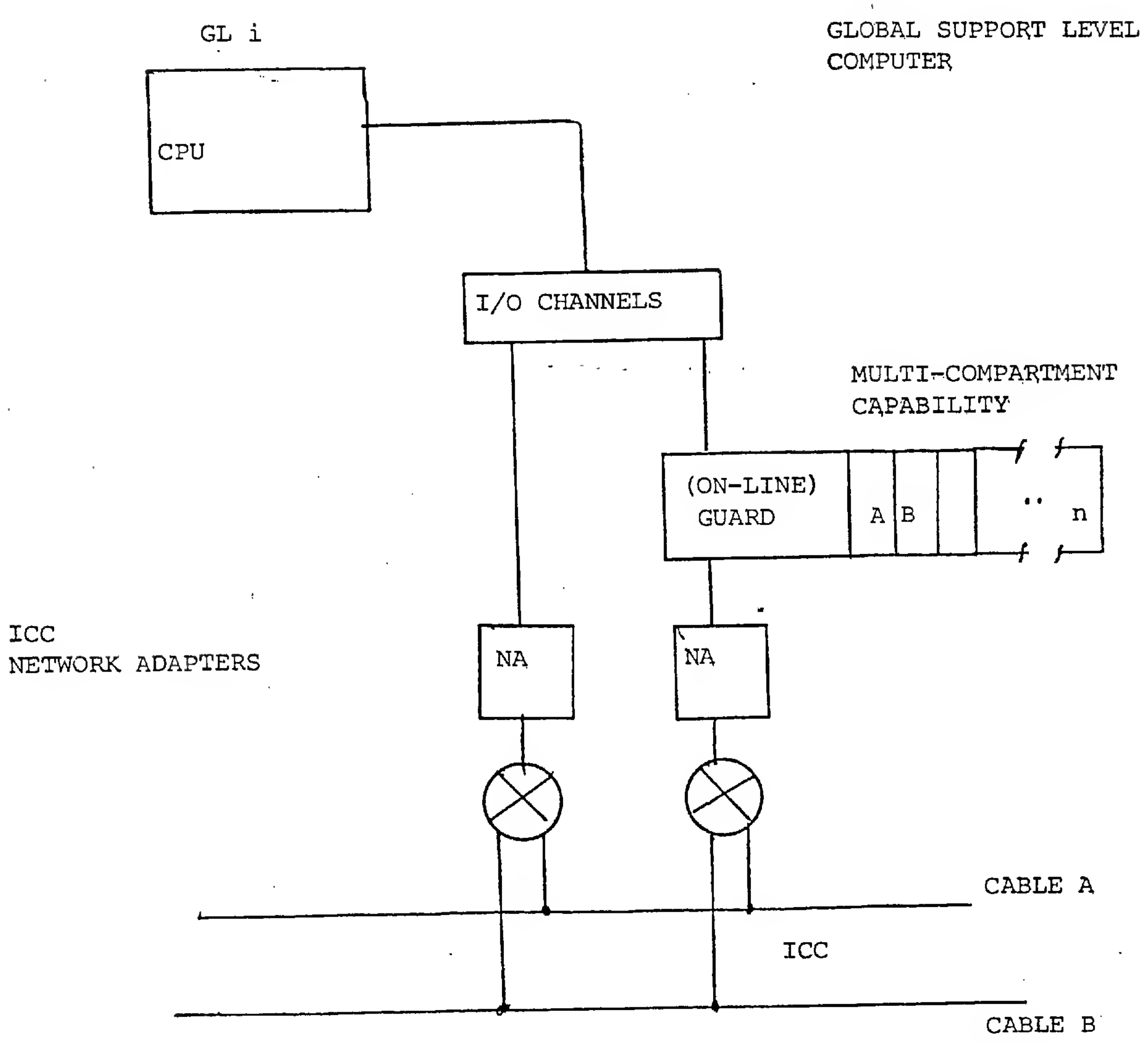
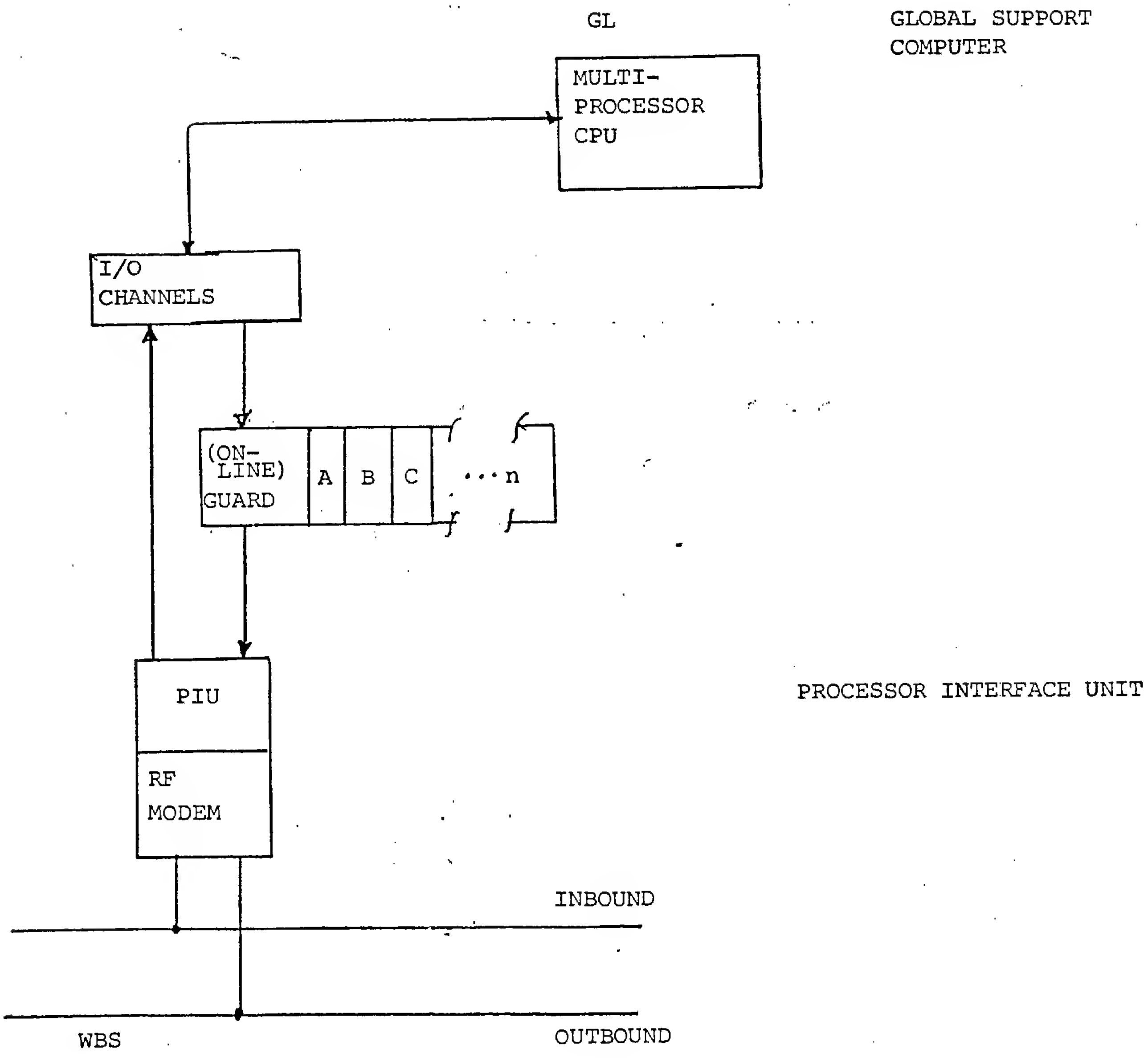


Figure 13

Safe (Guard) ICC Configuration



NOTE: In the ICC or WBC configuration, the structure and function of the Guard checksum subsection is identical to that of the Guard device proposed for the present RECON system. The only change is in the I/O interface structure of the Guard.

Figure 14

Safe (Guard) WBC Configuration

APPENDIX E

COMPARISON OF ALTERNATIVES TO SOLVING RECON SECURITY PROBLEM

A summary of the advantages and disadvantages of the various methods proposed for the solution of the RECON security problem is attached.

A COMPARISON OF VARIOUS ALTERNATIVES
TO SOLVING THE RECON SECURITY PROBLEM

	Present RECON	KSOS	Separate Systems	Filter	Authentication
Direct (internal) Penetration	No defense	Good defense Very low risk	Zero risk Best defense	No defense	No defense
Trapdoor (external) Penetration	No defense	No defense	Zero risk	No defense	Probability of unauthorized release is 5.24 x 10^{-20}
Spillage	No defense	No defense Very low risk of software error	Zero risk	No defense	Very low risk (guard machine fails and RECON processor fails)
Change of Functionality	No	None	? - could be large	No	No change for internal users, external users see a batch-only system
Modification to RECON ?	None	Substantial	None - some minor new software	Moderate	Some
New Hardware Required ?	None	Yes	Substantial (whole new system)	None	Yes - guard processor and input citation authenticator
Number of Access Classes Permitted	One (Agency internal)	Unknown - should be unlimited	Two	Unlimited	Several hundred
Cost	None	Very high 2 million +	Highest 2-5 million	Under $100,000	$250,000 - $300,000
Lead Time	None	3-5 years	2-3 years	6 months	1 - 1½ years